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Estimation of the Escapement of Chinook Salmon in the Unuk River in 2001

by

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and

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July 2003

Alaska Department of Fish and Game

Division of Sport Fish



Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
metric ton	mt
milliliter	ml
millimeter	mm

Weights and measures (English)

cubic feet per second	ft ³ /s
foot	ft
gallon	gal
inch	in
mile	mi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

all commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
all commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
compass directions:	
	east E
	north N
	south S
	west W
copyright	©
corporate suffixes:	
	Company Co.
	Corporation Corp.
	Incorporated Inc.
	Limited Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
id est (that is)	i.e.,
latitude or longitude	lat. or long.
monetary symbols (U.S.)	\$, ¢
months (tables and figures): first three letters	Jan., ..., Dec
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

alternate hypothesis	H _A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	F, t, χ^2 , etc.
confidence interval	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
	=
equals	=
expected value	E
fork length	FL
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log ₂ , etc.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
not significant	NS
null hypothesis	H ₀
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
standard length	SL
total length	TL
variance	var

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UNUK RIVER IN 2001**

by

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TABLE OF CONTENTS

	Page
LIST OF TABLES	ii
LIST OF FIGURES.....	ii
LIST OF APPENDICES	ii
ABSTRACT	1
INTRODUCTION.....	1
STUDY AREA.....	3
METHODS.....	3
Event 1: Sampling in the lower river	3
Event 2: Sampling on the spawning grounds.....	5
Abundance by size	5
Age and sex composition	8
Expansion factor	9
RESULTS.....	9
Tagging, recovery and abundance	9
Estimates of age and sex composition	11
Expansion factor	11
DISCUSSION.....	14
CONCLUSION AND RECOMMENDATIONS	21
ACKNOWLEDGMENTS	21
LITERATURE CITED	21
APPENDIX A	23

LIST OF TABLES

Table	Page
1. Capture histories for large chinook salmon in the population spawning in the Unuk River in 2001	8
2. Numbers of chinook salmon marked in the lower Unuk River and inspected for marks on the spawning grounds of the Unuk River in 2001 by size group	10
3. Number of marked large and medium chinook salmon released in the lower Unuk River and recaptured, by marking period, and the number examined for marks by recovery location, 2001	14
4. Peak survey counts, mark-recapture estimates of abundance, expansion factors, and other statistics for medium and large chinook salmon in the lower Unuk River (1994, 1997–2001)	15
5. Estimated age and sex composition of the escapement of medium and large chinook salmon in the Unuk River in 2001 as determined from spawning grounds samples	17
6. Estimated average length (MEF in mm) by age, sex, and sampling event chinook salmon sampled on the Unuk River in 2001	18
7. Chinook salmon released and recaptured during Event 1 in the lower Unuk River in 2001 and the elapsed time between release and recapture.	19

LIST OF FIGURES

Figure	Page
1. Behm Canal area in Southeast Alaska and location of major chinook salmon systems and hatcheries	2
2. Unuk River area in Southeast Alaska, showing major tributaries, barriers to chinook salmon migration, and location of ADF&G research sites	4
3. Location of the set gillnet site (SN1) on the lower Unuk River in 2001	6
4. Detailed drawing of the net placement used at the set gillnet site on the lower Unuk River in 2001	6
5. Effort (in hours of soaktime) and catch of chinook salmon by statistical week at SN1 on the Unuk River, 2001	10
6. Cumulative relative length frequencies of medium chinook salmon marked in the lower Unuk River in 2001 compared with those inspected and recaptured on the spawning grounds	12
7. Cumulative relative length frequencies of large chinook salmon marked in the lower Unuk River in 2001 compared with those inspected and recaptured on the spawning grounds	13
8. Numbers of chinook salmon sampled by length and age at all seven tributary spawning sites sampled on the Unuk River in 2001	16
9. The elapsed time between release and recapture of chinook salmon caught multiple times in the lower Unuk River set gillnets in 2001 by date of release, fish length, and age of fish	20

LIST OF APPENDICES

Appendix	Page
A1. Numbers of Unuk River chinook salmon fall fry and spring smolt captured and tagged with coded-wire tags, 1992 brood year to present	25
A2. Detection of size-selectivity in sampling and its effects on estimation of size composition	26
A3. Numbers by sex and age for chinook salmon sampled on the Unuk River spawning grounds in 2001 by location, gear, and size group, and in the lower river gillnet samples	27
A4. Estimated annual escapement of chinook salmon in the Unuk River by age class and sex, 1997–2001	30
A5. Numbers of adult Unuk River chinook salmon adults examined for adipose finclips, sacrificed for CWT sampling purposes, valid CWT tags decoded, percent of the marked fraction carrying germane CWTs, percent adipose clipped, and estimated fraction of the sample carrying valid CWTs, 1992 brood year to present	31
A6. Estimated abundance of the spawning population of large chinook salmon in the Unuk River, 1977–2001	33
A7. Estimation of overwinter survival of Unuk River chinook salmon fingerlings, 1992–1998 brood years	34
A8. Estimation of Unuk River chinook salmon smolt and fingerling abundance, 1992–1998 brood years	36
A9. Computer files used to estimate spawning abundance of chinook salmon in the Unuk River in 2001	37

ABSTRACT

The abundance of medium and large chinook salmon *Oncorhynchus tshawytscha* that returned to spawn in the Unuk River in 2001 was estimated using a two-event mark-recapture experiment. Biological data were collected during both events. Fish were captured during event 1 in the lower Unuk River using set gillnets from 11 June through mid-August. Each healthy fish was individually marked with a solid-core spaghetti tag sewn through its back and was given two secondary batch marks in the form of an upper-left operculum punch and removal of the left axillary appendage. In event 2, fish were examined on the spawning grounds from July through August to estimate the fraction of the population that had been marked. Abundance of large chinook salmon (≥ 660 mm mid-eye to fork [MEF]) was estimated to be 10,541 (SE = 1,181), estimated from 778 tagged and 74 recaptured fish out of 1,014 examined upstream. Abundance of medium-sized fish (401–659 mm MEF) was estimated to be 769 (SE = 124), by expanding the estimate of large fish by the estimated size composition of fish sampled during event 2.

An estimated 17% of the spawning population was sampled during the project. Peak survey counts in August totaled 2,019 large chinook salmon, about 19% of the mark-recapture estimate of large fish, similar to fractions seen in previous years. The mean expansion factor through 2001 is 4.99 (SD = 0.53) for estimating total escapement from survey counts. Of the spawning population >400 mm MEF, 8.4% (SE = 1.2%) were age-1.2 fish from the 1997 brood year, 61.2% (SE = 1.6%) were age-1.3 fish, and 29.5% (SE = 1.4%) were age-1.4 fish.

Key words: escapement, large and medium chinook salmon, Unuk River, mark-recapture, set gillnet, spaghetti tag, operculum punch, axillary appendage, Petersen model, peak survey counts

INTRODUCTION

The Unuk, Chickamin, Blossom, and Keta rivers in Southeast Alaska (SEAK) are four of eleven escapement indicator streams for chinook salmon *Oncorhynchus tshawytscha* (Pahlke 1997a). These four systems traverse the Misty Fjords National Monument and flow into Behm Canal, a narrow saltwater passage east of Ketchikan (Figure 1). Peak single-day aerial and foot survey counts of “large” chinook salmon ≥ 660 mm mid-eye to fork of tail (MEF) have been used as indices of escapement in each of these systems. These indices are roughly dome-shaped when plotted against time (since 1975) with peak values occurring between 1987 and 1990 (Pahlke 1997a). Peak 1987–1990 values of escapement are two to five times greater than the “baseline” (1975–1980) or current values of the index.

Several consecutive low survey counts in the early 1990s generated concern by 1992 for the health of the Behm Canal chinook stocks. In response, the Division of Sport Fish of the Alaska Department of Fish and Game (ADF&G) began a research program on the Unuk River, which is the largest chinook salmon producer in Behm Canal. Goals

of the program were to estimate smolt production and overwinter survival, adult escapement, total run size, exploitation rates, harvest distribution, and marine survival. These goals are being accomplished by inriver adult escapement and coded-wire tag projects and marine catch sampling programs.

The current escapement goal for the Unuk River is 650–1,400 large fish counted in surveys, or about 3,000–7,000 large fish total escapement (McPherson and Carlile 1997). Only large fish are counted in aerial surveys, because they can be distinguished with more confidence from other species that may be present because of their size and color. For our purposes, chinook salmon ≥ 660 mm MEF are considered large and generally consist of fish 3-ocean age or older. Nearly all females in the spawning population are large in size. Chinook salmon 401 mm–659 mm MEF are considered medium fish, and chinook salmon ≤ 400 mm MEF are considered small fish. Indices of escapement on the Unuk River are determined each year by summing the peak counts of large spawners observed during aerial and foot surveys in six tributaries: Cripple, Gene’s Lake, Kerr, Clear, and Lake creeks plus the Eulachon River (Pahlke 1997a) (Figure 2).

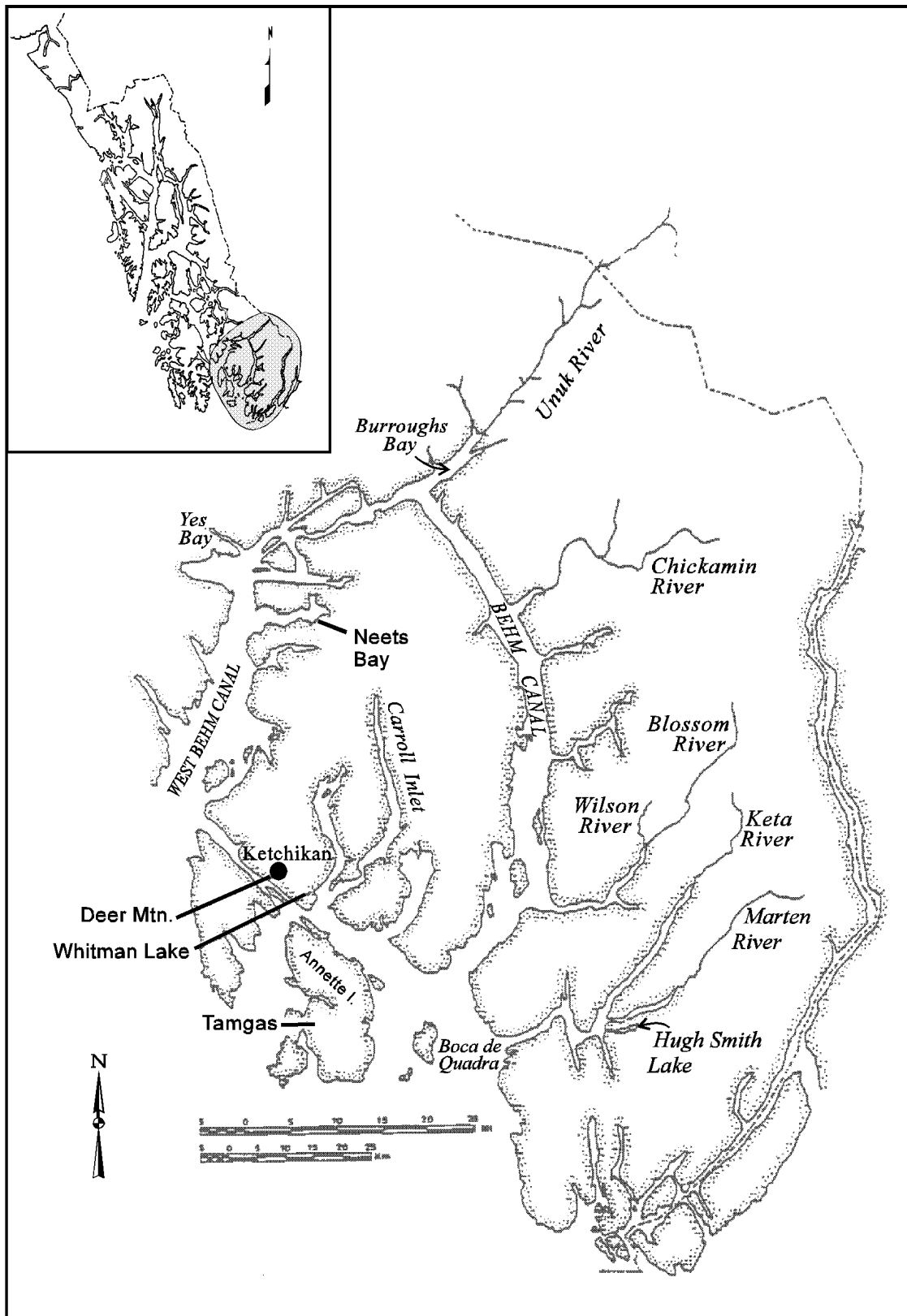


Figure 1.—Behm Canal area in Southeast Alaska and location of major chinook salmon systems and hatcheries.

Mark-recapture and radiotelemetry studies were conducted in 1994 (Pahlke et al. 1996). Mark-recapture studies have also been conducted annually from 1997 through 2000 (Jones et al. 1998; Jones and McPherson 1999, 2000, 2002). The radiotelemetry study indicated that 83% (SE = 9%) of all spawning occurred in the six tributaries surveyed. The mark-recapture experiments in 1994 and 1997 through 2000 estimated that an average of 4,302 large chinook salmon entered the river during those years with a range of 2,970 (1997) to 5,872 (2000). Survey counts during those years averaged 842 large chinook salmon, or 19.2% of the mark-recapture estimates, with a range of 636 (1997) to 1,341 (2000). The highest recorded survey count of 2,126 large fish occurred in 1986 (Pahlke 1997a). Average peak survey counts in the six index tributaries of the Unuk River from 1978–2001 are distributed as follows: Cripple Creek (425 fish, 38%), Gene's Lake Creek (337 fish, 30%), Eulachon River (192 fish, 17%), Clear Creek (97 fish, 8%), Kerr Creek (45 fish, 4%), and Lake Creek (32 fish, 3%). Cripple Creek and Gene's Lake Creek are not surveyed from the air because of heavy canopy cover; survey counts in these areas are made on foot. All other index areas are surveyed by helicopter or on foot (Pahlke 2001).

Other studies on the Unuk River were based on coded-wire tags (CWTs) inserted in chinook salmon juveniles from the 1982–1986 brood years (Pahlke 1995). Indications from this research were that commercial and sport harvest rates on the Unuk River chinook salmon stock (age-1.1–1.5) ranged between 14% and 24%; however, the precision of the harvest estimates was low, and escapement was inferred from the 1994 mark-recapture study expansion factor of 6.5 (~15% of spawners counted) and an alternative expansion factor of 4.0 (25% of spawners counted).

Starting in 1993, chinook salmon young-of-the-year (YOY) fingerlings were tagged with CWTs on the Unuk River. From 1993 through 2001 a total of 302,479 chinook (fall) fingerlings have been tagged, at an annual average of 33,609 and a range of 13,789 (1993) to 61,905 (1997). Tagging of chinook smolt commenced in spring 1994, and 80,803 smolt have been tagged through 2001 at an annual average of 10,100 and a range of 2,642 (1994) to 17,121 (1998)(Appendix A1).

The current stock assessment program for adult escapement of chinook salmon to the Unuk River has three primary objectives: (1) to estimate escapement; (2) to estimate age, sex, and length distribution in the escapement; and (3) to estimate the fraction of fish possessing CWTs by brood year. Meeting this last objective is essential to estimating harvest of this stock in current and future sport and commercial fisheries. Together harvest and escapement data will enable us to estimate total run size, exploitation rates, harvest distribution, and marine survival for this stock, an indicator stock for southern Southeast Alaska.

STUDY AREA

The Unuk River originates in a heavily glaciated area of northern British Columbia and flows for 129 km where it empties into Burroughs Bay, 85 km northeast of Ketchikan, Alaska. The Unuk River drainage encompasses an area of approximately 3,885 km² (Pahlke et al. 1996). The lower 39 km of the Unuk River are in Alaska (Figure 2), and in most years, the Unuk River is the fourth or fifth largest producer of chinook salmon in Southeast Alaska.

METHODS

A two-event mark-recapture experiment for a closed population was used to estimate the number of immigrant medium and large chinook salmon to the Unuk River in 2001. Fish were captured using set gillnets in the lower river for the first event and were sampled for marks with a variety of gear types on the spawning grounds for the second event.

EVENT 1: SAMPLING IN THE LOWER RIVER

Adult chinook salmon were captured using set gillnets as they immigrated into the lower Unuk River between 11 June and 21 August 2001. The set gillnets were 37 m (120 ft) long by 4 m (14 ft) deep with 18 cm (7¼") stretch mesh and a loose hanging ratio of about 2.2:1. One site (SN1) was used exclusively for set gillnets fishing in 2001 and has remained the same since 1997. This site (SN1) is located approximately 2 miles upstream on the south channel, mainstem of the lower

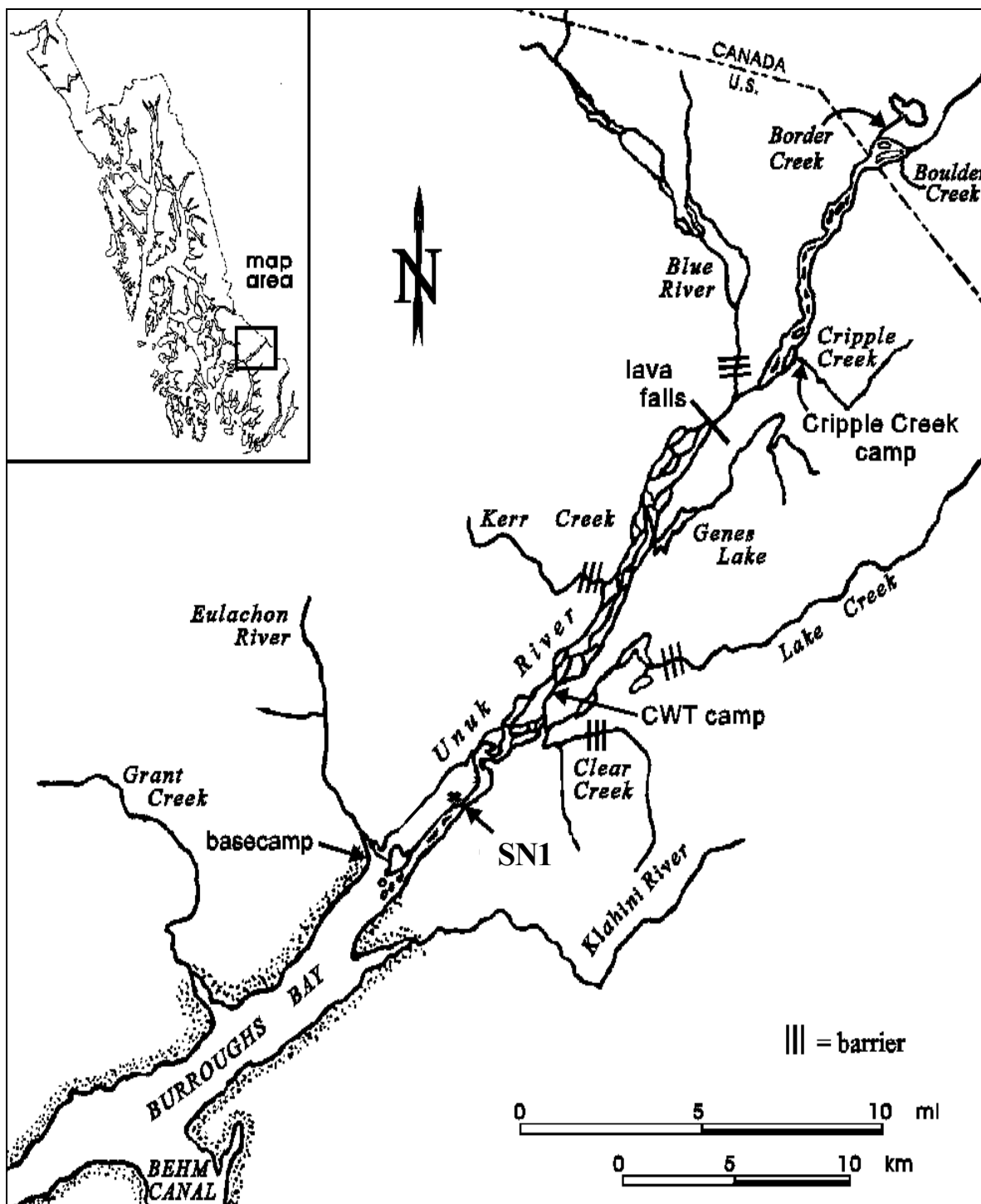


Figure 2.—Unuk River area in Southeast Alaska, showing major tributaries, barriers to chinook salmon migration, and location of ADF&G research sites.

Unuk River well below all known spawning areas except the Eulachon River (Figure 3).

Two back-to-back shifts of personnel fished two set gillnets at SN1 (Figure 4) 12 hours per day, 6 days per week. Crew shifts were staggered during the week so that at least one shift fished each day of the week whenever possible. One net was set perpendicular to the main flow of the Unuk River; it was attached to shore and ran directly across a small slough to a fixed buoy placed about 3 m downstream of a small island. Another net was attached to the same fixed buoy and trailed downstream along the eddy line formed between the mainstem and the side slough.

All fish captured, regardless of health, were sampled to estimate the age, sex, and length (ASL) composition of the escapement. Length in MEF was measured to the nearest 5 mm, and sex was determined from external, dimorphic characteristics. Five scales were taken about 1" apart within the preferred area on the left side of each fish. The preferred area is two to three rows above the lateral line and between the posterior terminus of the dorsal fin and the anterior margin of the anal fin (Welanders 1940). Scales were mounted on gum cards that held scales from ten fish, as described in ADF&G (1993). The age of each fish was later determined from the pattern of circuli (Olsen 1995), seen on images of scales impressed into acetate cards magnified 70× (Clutter and Whitesel 1956). The presence or absence of an adipose fin was also noted for each sampled fish. Those fish missing adipose fins and < 700 mm MEF (jacks) were sacrificed, and their heads were sent to the ADF&G Tag and Otolith Lab for detection and decoding of CWTs.

All captured fish judged healthy and possessing adipose fins were marked in three ways: a uniquely numbered solid-core spaghetti tag sewn through the back, a clip of the left axillary appendage (LAA), and a left upper operculum punch (LUOP) 0.63 cm (¼") in diameter then released. The axillary clip and operculum punch enable the detection of tag loss. The spaghetti tag consisted of a 5.71 cm (2¼") section of laminated Floy tubing shrunk onto a 38 cm (15") piece of 80-lb test monofilament fishing line.

The monofilament was sewn through the back just behind the dorsal fin and secured by crimping both ends of the monofilament in a line crimp. The excess monofilament was then trimmed off. Each spaghetti tag was individually numbered and stamped with an ADF&G phone number.

EVENT 2: SAMPLING ON THE SPAWNING GROUNDS

Chinook salmon of all sizes were sampled on Boundary Lake Creek (also known as Border Creek); on Chum, Clear, Cripple, Gene's Lake, Kerr, and Lake creeks; and on the Eulachon River in 2001 (Figure 2). Various methods were used to capture fish, including rod and reel, spears, dip nets, gillnets, and carcass surveys. Use of a variety of gear types has been shown to produce unbiased estimates of age, sex, and length composition (McPherson et al. 1997; Jones et al. 1998; Jones and McPherson 1999, 2000, 2002). A hole was punched into the left lower operculum of all inspected fish (LLOP) to prevent double sampling. These fish were closely examined for presence of a tag, an LUOP, an LLOP, and an LAA; for a missing adipose fin, and were sampled to obtain ASL data by the same techniques employed in the lower river. For chinook salmon missing adipose fins, all fish <700 mm MEF as well as spawned-out fish of all sizes were sacrificed to retrieve CWTs. Heads so collected were sent to the ADF&G Tag Lab for dissection and decoding of tags. Foot surveys were also conducted on each of the sampled tributaries on at least one occasion. Multiple surveys were spaced approximately one week apart and when possible, coincided with the historical peak observed abundance.

ABUNDANCE BY SIZE

We stratified the mark-recapture experiment by size because we desired an estimate for larger fish to compare with counts from the aerial surveys. Abundance of large (≥660 mm MEF) fish was estimated using Chapman's modification of the Petersen estimator (Seber 1982). Estimated abundance (\hat{N}_L) was calculated

$$\hat{N}_L = \frac{(M_L + 1)(C_L + 1)}{(R_L + 1)} - 1 \quad (1)$$

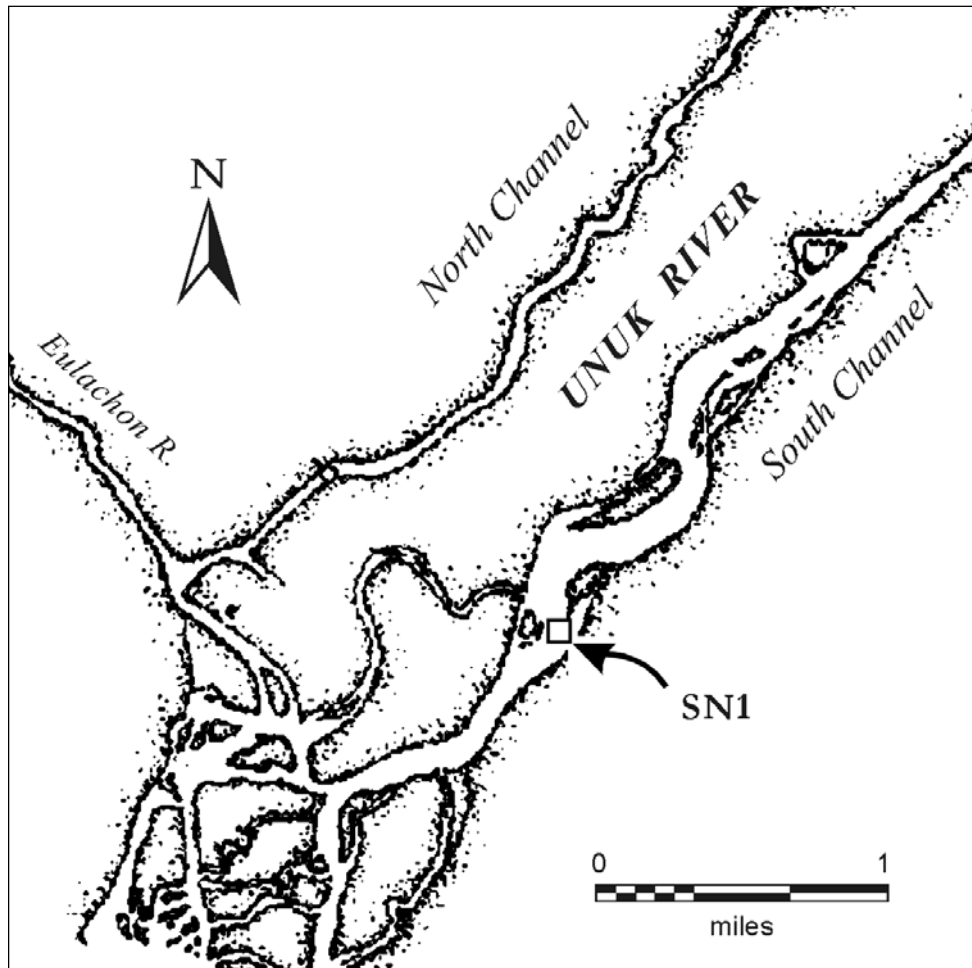


Figure 3.—Location of the set gillnet site (SN1) on the lower Unuk River in 2001.

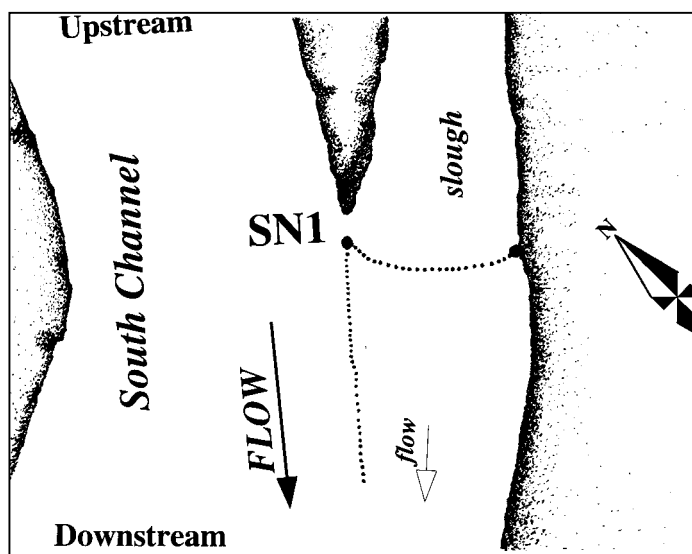


Figure 4.—Detailed drawing of the net placement used at the set gillnet site (SN1) on the lower Unuk River in 2001.

where M_L is the number of large fish sampled and marked during event 1, C_L is the number of large fish sampled for marks during event 2, and R_L is the number of C_L that possessed marks applied during event 1. The general conditions that must hold for \hat{N}_L to be a consistent estimate of abundance are in Seber (1982) and may be cast as follows:

- (a) every fish had an equal probability of being marked in event 1, or every fish had an equal probability of being inspected for marks in event 2, or marked fish mixed completely with unmarked fish in the population between events; and
- (b) there was no recruitment to the population between events; and
- (c) there was no tag-induced mortality; and
- (d) fish did not lose their marks in the time between events; and
- (e) all marked fish were recognized.

To provide evidence that condition *a* was met, two chi-square tests were performed: (1) for equal proportions of marks by capture area in event 2; and (2) equal probabilities of recapture in event 2 independent of when the fish was marked. If the null hypothesis of either test was not rejected, the pooled Petersen estimator (equation 1) should be a consistent estimator; otherwise a temporally or spatially stratified estimator should be employed. Tests were made separately using the SPAS software program (Arnason et al. 1996).

The possibility of size and gender selective sampling was also investigated, because condition *a* can also be violated in this manner. The hypothesis that fish of different sizes were captured with equal probability was tested using two Kolmogorov-Smirnov (K-S) 2-sample tests ($\alpha = 0.1$, Appendix A2). Evidence for gender-selective sampling was sought using simple chi-square analyses.

Regarding condition *b*, recruitment of fish into the population should be a moot issue if efforts at SN1 span the entire immigration. We were not

able to investigate condition *c*; however, we were careful to not harm or stress fish, and we did not mark obviously injured fish. Radio telemetry studies in 1994 and 1996 showed that chinook salmon survive and spawn after having been captured as in this project (Pahlke et al. 1996; Pahlke 1997b). The effect of tag loss (condition *d*) is virtually eliminated by using the two secondary marks, and all fish captured during event 2 were inspected for marks. Double sampling of fish was avoided by marking all sampled fish during event 2 with a LLOP.

Variance, bias, and confidence intervals for \hat{N}_L were estimated with modifications of bootstrap procedures in Buckland and Garthwaite (1991). Fish were divided into four capture histories (Table 1). A bootstrap sample was built by drawing with replacement a sample of size \hat{N}_L from the empirical distribution defined by the capture histories. A new set of statistics from each bootstrap sample $\{\hat{M}_L^*, \hat{C}_L^*, \hat{R}_L^*\}$ was generated, along with a new estimate for abundance \hat{N}_L^* . A thousand such bootstrap samples were drawn, creating the empirical distribution $F(\hat{N}_L^*)$, which is an estimate of $F(\hat{N}_L)$. The difference between the average $\bar{\hat{N}}_L^*$ of bootstrap estimates and \hat{N}_L is an estimate of statistical bias in the latter statistic (Efron and Tibshirani 1993, Section 10.2). Confidence intervals were estimated from $\hat{F}(\hat{N}_L^*)$ with the percentile method (Efron and Tibshirani 1993, Section 13.3). Variance was estimated as

$$\text{var}(\hat{N}_L^*) = (B-1)^{-1} \sum_{b=1}^B (\hat{N}_{L(b)}^* - \bar{\hat{N}}_L^*)^2 \quad (2)$$

where B is the number of bootstrap samples (1,000).

Because we failed to capture enough marked medium sized fish during Event 2 to provide an unbiased estimate, data from the mark-recapture experiment could not be used to estimate the abundance of medium-sized chinook salmon (Seber 1982). Consequently, the abundance of medium-sized fish was estimated indirectly by

Table 1.—Capture histories for large chinook salmon in the population spawning in the Unuk River in 2001 (notation explained in text).

Capture history	Large	Source of statistics
Marked and not recaptured in tributaries	704	$\hat{M}_L - R_L$
Marked and recaptured in tributaries	74	R_L
Not marked, but captured in tributaries	940	$C_L - R_L$
Not marked and not sampled in tributaries	8,823	$\hat{N}_L - \hat{M}_L - C_L + R_L$
Effective population for simulations	10,541	\hat{N}_L^+

expanding the estimate for large fish by the estimated size composition of the spawning escapement:

$$\hat{N}_M = \hat{N}_L \left(\frac{1}{\hat{\phi}} - 1 \right) \quad (3)$$

where \hat{N}_M is the estimated spawning escapement of medium-sized fish and $\hat{\phi}$ is the estimated fraction of large fish in the spawning population of large and medium-sized chinook salmon (McPherson et al. 1996). Testing of the spawning grounds samples collected in 1994 and 1997–2000 has consistently found no evidence of size or gender selectivity (Pahlke et al. 1996; Jones et al. 1998; Jones and McPherson 1999, 2000, 2002).

Variance and confidence intervals for \hat{N}_M were estimated through simulation by treating the number of large-sized chinook salmon sampled on the spawning grounds as a binomial variable $n_L^* \sim \text{binom}(\hat{\phi}, n)$, where n is the number of spawning ground samples >400 mm MEF. A thousand such simulated samples were drawn for

each $\hat{n}^* = n_L^* / n$, creating the empirical distribution $\hat{F}(\hat{\phi}^*)$ as an estimate of $F(\hat{\phi})$. Empirical distributions of $\hat{F}(\hat{\phi}^*)$ and $F(\hat{N}_L^*)$ were matched through equation (3) to produce the distribution $\hat{F}(\hat{N}_M^*)$ from which the estimate $v(\hat{N}_M^*)$ and confidence intervals for \hat{N}_M were produced with methods described above (McPherson et al. 1996).

AGE AND SEX COMPOSITION

The proportion of the spawning population composed of a given age within the medium or large fish size classes was estimated as a binomial variable:

$$\hat{p}_{ij} = \frac{n_{ij}}{n_i} \quad (4)$$

$$\text{var}(\hat{p}_{ij}) = \frac{\hat{p}_{ij}(1 - \hat{p}_{ij})}{n_i - 1} \quad (5)$$

where \hat{p}_{ij} is the estimated proportion of the population of age j in sized group i , n_{ij} is the number of chinook salmon of age j of size group i , and n_i is the number of chinook salmon in the sample n of size group i . Information gathered during event 1 was not used to estimate age or sex composition as tests (described above) showed sampling in event 1 was biased towards catching large fish. Samples gathered at each spawning tributary were pooled together because no differences in age composition were apparent between tributaries sampled. Numbers of spawning fish by age were estimated as the sum of the products of estimated age composition and estimated abundance within a size category

$$\hat{N}_j = \sum_i (\hat{p}_{ij} \hat{N}_i) \quad (6)$$

and

$$\text{var}(\hat{N}_j) = \sum_i \left(\text{var}(\hat{p}_{ij}) \hat{N}_i^2 + \text{var}(\hat{N}_i) \hat{p}_{ij}^2 - \text{var}(\hat{p}_{ij}) \text{var}(\hat{N}_i) \right) \quad (7)$$

with variance calculated according to procedures in Goodman (1960).

The proportion of the spawning population >400 mm MEF composed of a given age was estimated as the summed totals across size categories

$$\hat{p}_j = \frac{\hat{N}_j}{\hat{N}} \quad (8)$$

and

$$\text{var}(\hat{p}_j) = \frac{\sum_i (\text{var}(\hat{p}_{ij}) \hat{N}_i^2 + \text{var}(\hat{N}_i) (\hat{p}_{ij} - \hat{p}_j)^2)}{\hat{N}^2} \quad (9)$$

where variance is approximated according to procedures in Seber (1982, p. 8–9).

Sex composition and age-sex composition for the entire spawning population and its associated variances were also estimated using the above equations by first redefining the binomial variables in samples to produce estimated proportions by sex \hat{p}_k , where k denotes gender (male or female), such that $\sum_k \hat{p}_k = 1$, and by age-sex \hat{p}_{jk} , such that $\sum_{jk} \hat{p}_{jk} = 1$.

EXPANSION FACTOR

An expansion factor ($\hat{\pi}$) for Unuk River chinook salmon in a calendar year is

$$\hat{\pi}_i = \hat{N}_i / C_i \quad (10)$$

$$\text{var}(\hat{\pi}_i) = \text{var}(\hat{N}_i) / C_i^2 \quad (11)$$

where i is the year (with a mark-recapture experiment), \hat{N}_i is the mark-recapture estimate of large chinook and C_i is the peak aerial survey count.

The mean expansion factor ($\bar{\pi}$) and its estimated variance are

$$\bar{\pi} = \sum_{i=1}^k \hat{\pi}_i / k \quad (12)$$

$$\text{var}(\bar{\pi}) = \sum_{i=1}^k (\hat{\pi}_i - \bar{\pi})^2 / (k-1) \quad (13)$$

where k is the number of years with mark-recapture experiments (five for the Unuk River at present, from 1997 to 2001).

The estimator for expanding peak survey counts into estimates of spawning abundance is

$$\hat{N}_t = \bar{\pi} C_t \quad (14)$$

$$\text{var}(\hat{N}_t) = C_t^2 \text{var}(\bar{\pi}) \quad (15)$$

RESULTS

TAGGING, RECOVERY AND ABUNDANCE

Of 946 chinook salmon sampled in the lower river, 854 were marked and released (Table 2). Approximately 94% of the chinook salmon marked during the first sampling event were captured between 9 June and 28 July, a period of time also characterized by relatively constant fishing effort at the set gillnets (Figure 5). Sixteen (16) fish were considered unhealthy upon capture and were not marked, and 1 fish received only a partial mark before escaping. Four (4) fish were censored from the experiment: 2 were non-random spawning grounds recoveries, 1 was recovered in the Chickamin River on 2 August, and 1 was recovered in the marine recreational fishery (District 101-80) on 16 July. Of the 854 fish marked, 4 were small, 71 were medium, 778 were large (including 1 with secondary and tertiary marks but no tag), and 1 was not measured for length. Of the fish caught and sampled at SN1, 101 were missing adipose fins, of which 21 were sacrificed; the rest were marked and released in good condition (Appendix A5). Of the total fish that were missing adipose fins and of those sacrificed, 62% and 86%, respectively, were males. Of 1,102 fish sampled in event 2, 12 were small, 74 were medium-sized, 1,014 were large, and 2 were not measured. During event 2, we recaptured 77 fish (i.e., fish previously marked in event 1), of which none were small, 3 were medium-sized, and 74 were large. Adipose fins were missing on 127 fish sampled during event 2, of which 50% were males. Sixty-seven (67) of these were sacrificed to retrieve a CWT; 48% of these were males (Appendix A5). Rate of tag loss was 10% for all recoveries; these fish were identified as being previously marked by the presence of the left upper operculum punch and a missing left axillary appendage.

Table 2.—Numbers of chinook salmon marked in the lower Unuk River and inspected for marks on the spawning grounds of the Unuk River in 2001, by size group.

	Length (MEF)			Total ^a
	0–400 mm	401–659 mm	>659 mm	
Released in event 1 with marks (M)	4	71	778	854
Inspected at:				
1. Upriver ^b				
Inspected (C)	0	30	407	437
Recaptured (R)	0	0	34	34
Recaptured/captured			0.084	0.078
2. Downriver ^c				
Inspected (C)	12	44	607	665
Recaptured (R)	0	3	40	43
Recaptured/captured		0.068	0.066	0.065
Total Inspected				
Inspected (C)	12	74	1,014	1,102
Recaptured (R)	0	3	74	77
Recaptured/captured		0.041	0.073	0.070

^a Totals include 1 fish released in event 1, and 2 fish inspected at Gene's Lake Ck. without measurements.

^b Includes Boulder, Boundary, Chum, and Cripple creeks.

^c Includes Clear, Gene's Lake, Kerr, and Lake creeks and the Eulachon River.

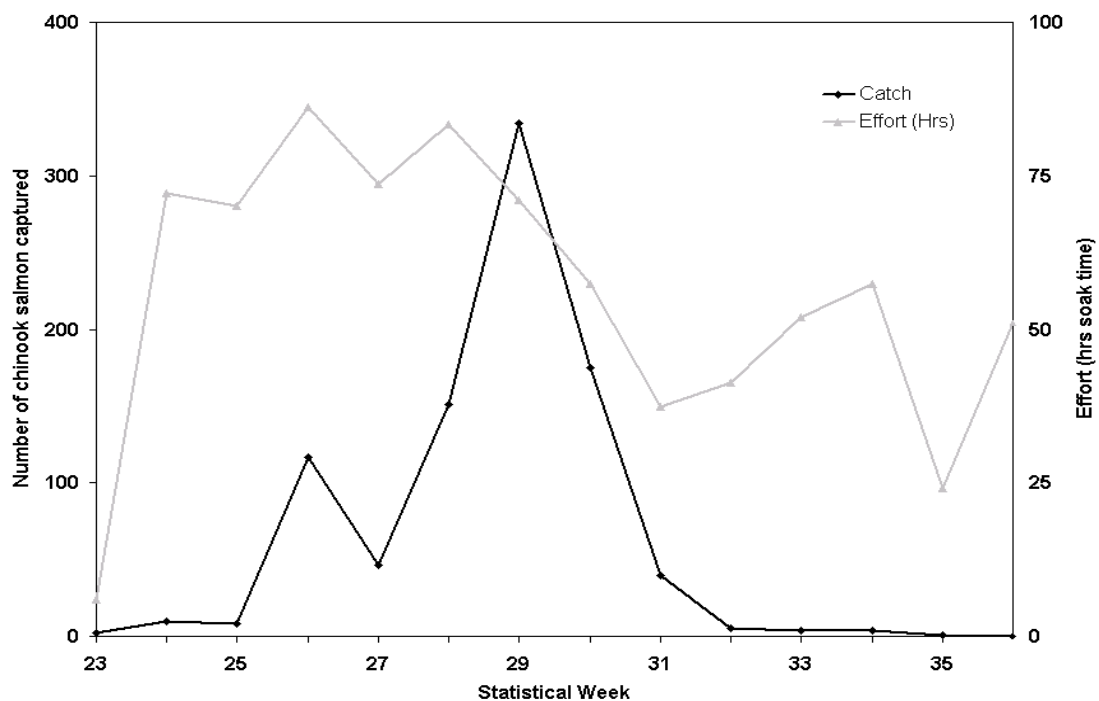


Figure 5.—Effort (in hours of soaktime) and catch of chinook salmon by statistical week at SN1 on the Unuk River, 2001.

Comparisons among length distributions provided evidence of size-selective sampling of medium-sized fish, but not of large fish. Too few medium-sized fish were recaptured (3) to provide a powerful enough test to detect size-selective sampling during event 2 (Figure 6, Panel B). However, tests showed that in general, medium-sized fish caught on the spawning grounds were smaller than those caught at SN1 (Figure 6, Panel A), which is evidence that size-selective sampling of medium-sized fish occurred during at least one event. In contrast, size distributions of large fish were similar across events (Figure 7), which is evidence against size-selective sampling of large fish in either event.

Chi-square tests suggested little evidence of gender selectivity between sampling events for large chinook salmon ($\chi^2 = 2.53$, $df = 1$, $P = 0.11$). Tests to determine temporal stratification were performed by stratifying the mark-recapture data into two time and recovery periods (Table 3). Results indicated that large chinook salmon marked early in the experiment (before July 16) and late in the experiment were equally likely to be recaptured ($\chi^2 < 0.03$, $df = 1$, $P = 0.87$). Similarly, the recapture rate during event 2 did not vary by sampling date ($\chi^2 = 1.27$, $df = 1$, $P = 0.26$). Thus, a pooled Petersen estimator was used to estimate the abundance of large fish (\hat{N}_L) on the spawning grounds in 2001 ($n_1 = 1,014$, $n_2 = 778$, $m_2 = 74$) as 10,541 (SE = 1,181) (Table 2). Statistical bias of the estimate was negligible (0.9%), and the 95% bootstrap confidence interval for the estimated abundance of large fish is 8,705 to 13,253 (Table 4).

Evidence of size selectivity during the marking process, and an insufficient sample size of marked chinook salmon inspected on the spawning grounds to provide an unbiased estimate of abundance, precluded our ability to use the mark-recapture data to estimate abundance of medium-sized chinook salmon (Seber 1982, p. 60). Consequently, by methods previously described, the abundance of medium-sized chinook salmon was estimated at 769 (SE = 124). Statistical bias of the estimate was 1.6% and the 95% bootstrap confidence interval for the

estimated abundance of medium fish is 557 to 1,068. Estimated abundance of all chinook salmon >400 mm MEF for 2001 is 11,310 (SE = 1,187).

ESTIMATES OF AGE AND SEX COMPOSITION

Over 90% of the estimated spawning population of chinook salmon >400 mm MEF was composed of age-1.3 (61.2%, SE = 1.6%) and age-1.4 (29.5%, SE = 1.4%) fish (Appendix A3, Figure 8). The dominance of the age-1.3 (1996 brood year) and age-1.4 (1995 brood year) was preceded in 2000 by similarly strong returns of chinook salmon from the 1995 and 1996 brood years. Approximately 50% of the spawning population of chinook salmon in 2001 were males, in contrast to the previous 4-year average of 62% (Table 5, Appendix A4). Age-1.2 fish constituted an estimated 86.5% (SE = 4.0%) of the medium-sized fish, 100% of which were males (Table 5). There were an estimated 5,697 (SE = 659) spawning females in 2001 (Table 5).

Estimated average lengths by age and sex were similar between events 1 and 2 in 2001 (Table 6). Tests determined no significant difference in the proportion of medium to large-sized fish sampled during event 1 versus event 2 ($\chi^2 = 1.86$, $df = 1$, $P = 0.17$). The gillnets used in event 1 were, however, biased towards capturing only the larger members of the medium population (see Figure 5, Panel A). In general, the length data gathered in event 2 during spawning grounds sampling is most appropriate for length composition analysis, since using a multitude of gear types to gather samples has been shown to reduce bias in age, sex, and length sampling for chinook salmon (Jones and McPherson 1999).

EXPANSION FACTOR

Of the estimated 10,541 large chinook salmon immigrating to the Unuk River in 2001, 2,019 (19%) were counted during peak survey counts. This percentage is similar to that of previous years, which ranged from 15% in 1994 to 23% in 2000 (Table 4). Using the 1997–2001 mark recapture estimates and peak survey counts, the mean expansion factor would therefore be 4.99 (SD = 0.53) (Table 4). The expansion factor for

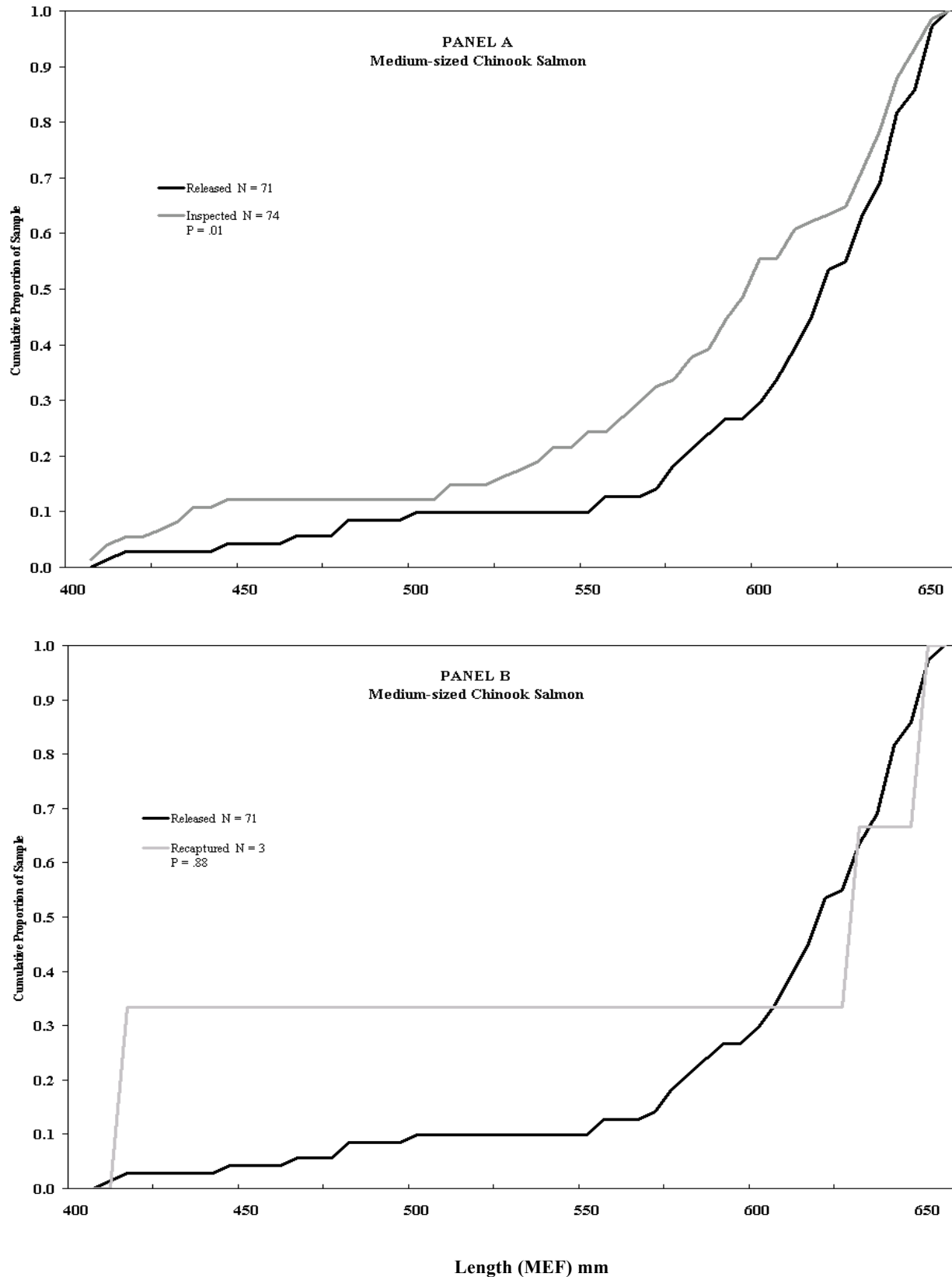


Figure 6.—Cumulative relative frequencies of medium chinook salmon (401–659 mm MEF) marked in the lower Unuk River in 2001 compared with those inspected and recaptured on the spawning grounds.

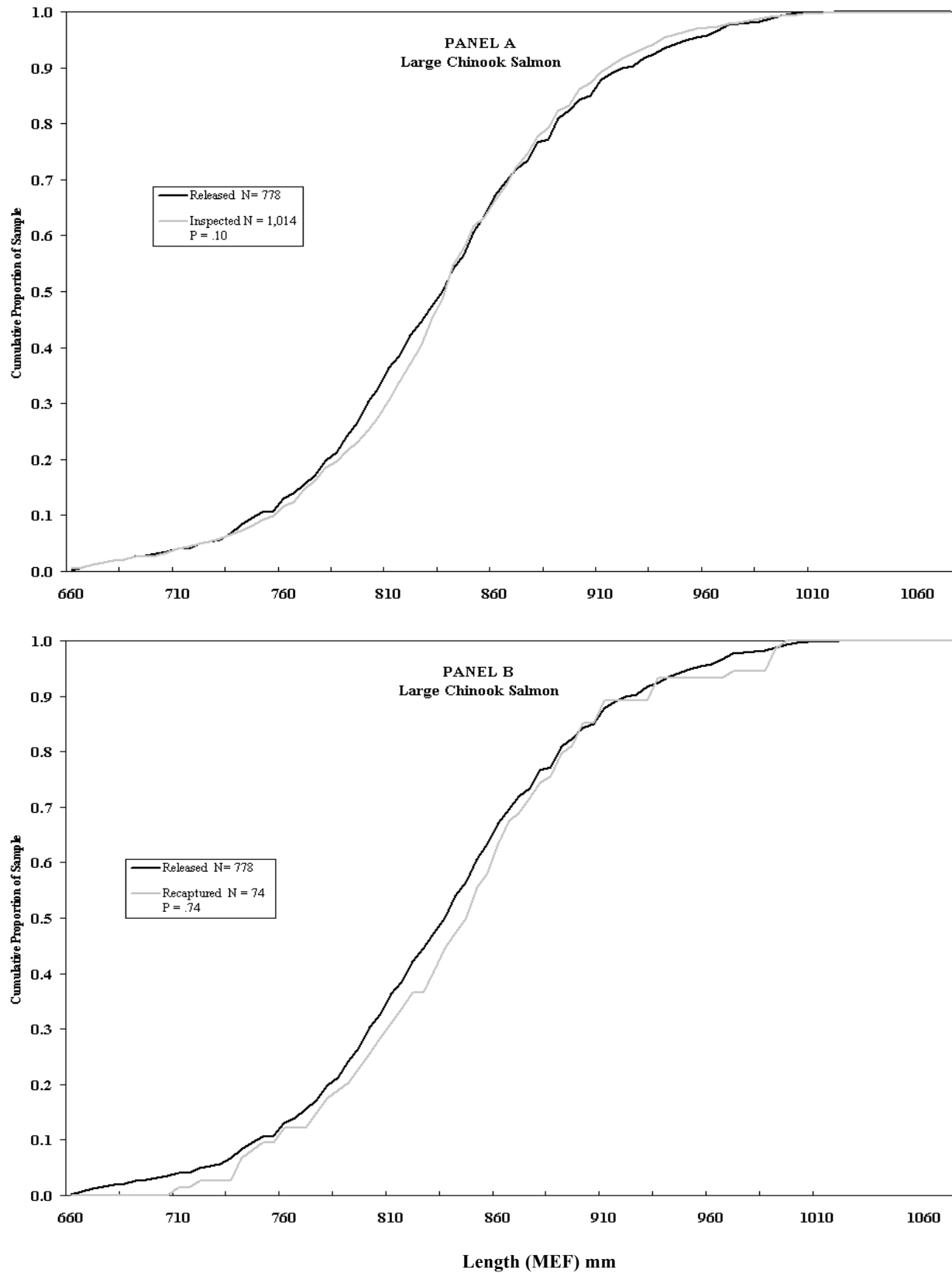


Figure 7.—Cumulative relative frequencies of large chinook salmon (>659 mm MEF) marked in the lower Unuk River in 2001 compared with those inspected and recaptured on the spawning grounds.

Table 3.—Number of marked large and medium chinook salmon released in the lower Unuk River and recaptured, by marking period, and the number examined for marks at each recovery location, 2001. Does not include recoveries with missing primary tags.

Marking dates	Number marked	Estimated fraction recovered	Recovery location		Total
			Downriver ^a	Upriver ^b	
LARGE CHINOOK SALMON					
6/09 to 7/15	345	0.084	12	17	29
7/16 to 8/21	433	0.088	23	15	38
Total/proportion	778	0.086	35	32	67
Number inspected			607	407	1,014
Fraction marked			0.058	0.079	0.066
MEDIUM CHINOOK SALMON					
6/09 to 7/15	29	0.034	1	0	1
7/16 to 8/21	42	0.024	1	0	1
Total/proportion	71	0.028	2	0	2
Number inspected			44	30	74
Fraction marked			0.045		0.027

^a Includes Clear, Gene's Lake, Kerr, and Lake creeks and the Eulachon River.

^b Includes Border, Boundary, Chum, and Cripple creeks.

1994 is not included due to the low relative precision of that estimate (54%) as compared to that of subsequent years (range of 18% in 1997 to 24% in 1999).

DISCUSSION

In previous years of study, chinook salmon tagged and released during Event 1 have shown a “sulking” behavior or a delay in upstream migration (Pahlke et al. 1996). In 2001, 50 fish were marked, released, and subsequently recaptured in Event 1. For these fish, the average time between release and recapture (e.g., an estimate of the “sulk” rate) was approximately 4 days and 5 hours, with a maximum period of over 24 days and a minimum of 31 minutes (Table 7). This rate does not appear to vary by length or age; however, a noticeable trend exists when examined by marking date. The “sulk” rate appears to be higher for fish marked earlier versus later in the project, and averaged 14.9 days for fish released in June and 2.1 days for those released in July (Figure 9). This phenomenon has been observed in other studies (Milligan et al. 1984; Johnson et al. 1992; Bendock and

Alexandersdottir 1993; Johnson 1993; Eiler et al. *In prep*) and is consistent with results obtained during previous chinook salmon mark-recapture experiments on the Unuk River (Jones et al. 1998; Jones and McPherson 1999, 2000, 2002).

Loss of tags was slightly higher than in previous years. Eight (8) of the 77 recaptures seen in event 2 (10.4%) were missing their tag. The average rate of tag loss from 1997 to 2000 was 8%, with a range of 3% observed in 1997 to 14% in 2000. This was likely a result of either applying too much pressure on the crimping tool, which can burn the monofilament leader and decrease its strength, or not enough pressure on the crimping tool resulting in an inadequate crimp. Of the 77 recaptured fish, 74 were large-sized with seven missing tags (9.5%) and 3 were medium-sized with one missing its tag (33%). In all cases, secondary marks were clearly visible on recaptured fish, once fish were in hand.

The validity of the medium-sized chinook salmon abundance estimate rests solely upon the degree to which the second sampling event was devoid of size-selectivity. Chinook salmon mark-recapture experiments have previously been conducted on

Table 4.–Peak survey counts, mark-recapture estimates of abundance, expansion factors and other statistics for medium (401–659 mm MEF) and large (>659 mm MEF) chinook salmon in the Unuk River (1994, 1997–2001).

	1994		1997		1998		1999		2000		2001		Average 1997–2001	
	Medium	Large	Medium	Large	Medium	Large	Medium	Large	Medium	Large	Medium	Large	Medium	Large
Survey count		711		636		840		680		1,341		2,019		1,103
m_2	0	10	16	78	15	79	13	50	8	69	3	74	11	70
n_1	15	161	75	307	87	466	125	380	128	570	71	778	97	500
n_2	38	313	156	761	217	707	251	523	158	719	74	1,014	171	745
Mark-recapture (M–R) estimate		4,623	701	2,970	1,198	4,132	2,267	3,914	2,278	5,872	769	10,541	1,443	5,486
SE (M–R)		1,266	138	271	253	394	537	480	675	620	124	1,181	345	589
Survey count/(M–R) (%)		15.4		21.4		20.3		17.4		22.8		19.2		20.2
CV (M–R) (%)		27.4	19.7	9.1	21.1	9.5	23.7	12.3	29.6	10.6	16.1	11.2	22.0	10.5
95% RP M–R estimate (%)		53.7	38.6	17.9	41.4	18.7	46.4	24.0	58.1	20.7	31.6	22.0	43.2	20.7
Expansion factor (EF)		6.50		4.67		4.92		5.76		4.38		5.22		4.99
SD (EF)		1.78		0.43		0.47		0.71		0.46		0.58		0.53
CV (EF) (%)		27		9		10		12		11		11		11
95% RP (EF) (%)		54		18		19		24		21		22		21
M–R lower 95% C.I.	2,992		489	2,499	815	3,433	1,506	3,110	1,358	4,848	557	8,705	766	4,331
M–R upper 95% C.I.	9,425		1,109	3,636	1,903	4,974	3,811	5,071	5,042	7,347	1,068	13,253	2,120	6,641
Estimated bias (%)			2.3	0.1	3.0	0.6	3.4	1.5	9.6	1.1	1.6	0.9	4.0	0.8

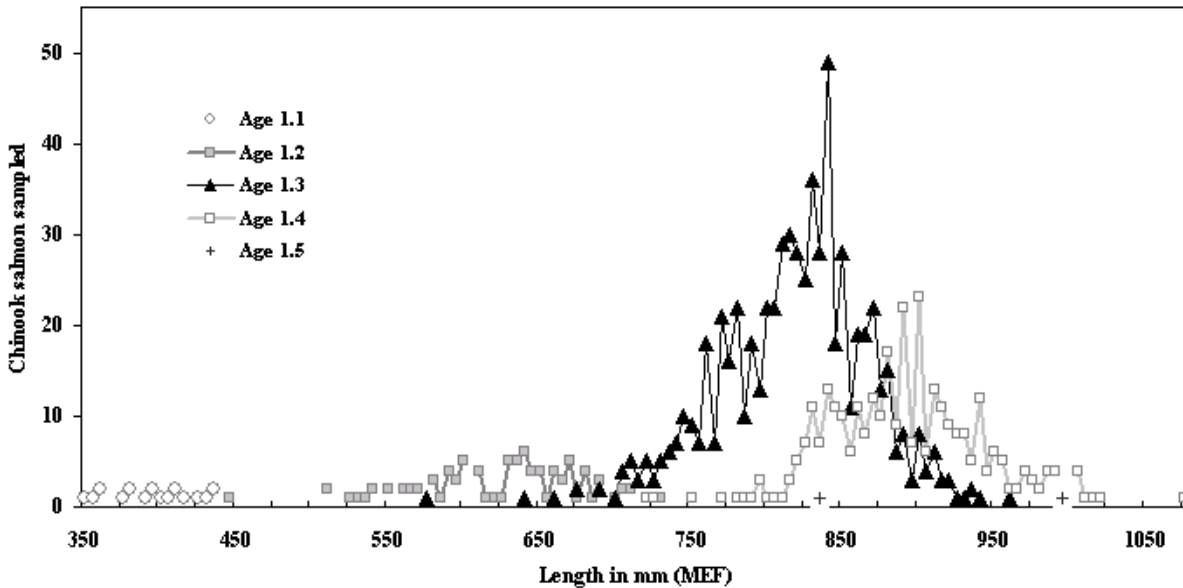


Figure 8.—Numbers of chinook salmon sampled by length and age at all seven tributary spawning sites sampled on the Unuk River in 2001.

the Unuk River in 1994 and 1997–2000. In 1994 it was determined that size-selective sampling occurred during the spawning grounds surveys, primarily as a result of an overreliance upon sampling carcasses and small sample size (Pahlke et al. 1996). In order to reduce bias in age, gender, and length composition estimates, sample sizes were increased and diverse techniques were used to obtain spawning grounds samples in 1997–2001. As a consequence, from 1997–2001 there has been no indication of size-selectivity during the second sampling event.

In 1994 and 1997–2000, the estimated abundance of large-sized chinook salmon as determined from mark-recapture experiments was considerably larger than corresponding estimates obtained from peak survey counts. Similarly, of the estimated 10,541 large chinook salmon immigrating to the Unuk River in 2001, 2,019 (19%) were counted in the peak survey count. This percentage is similar to that of previous years, which ranged from 15% in 1994 to 23% in 2000. These data can be used to calculate an expansion factor with which to expand past survey counts into estimates of total escapements for those years with survey counts but without

escapement estimates. Using 1997–2001 mark recapture estimates and peak survey counts, the mean expansion factor would be 4.99 (SD = 0.53). The expansion factor for 1994 is not included, because of the low relative precision of that estimate (54%) compared to that of subsequent years (range of 18% in 1997 to 24% in 1999). Analysis of this data continues, with the expectation of estimating total large spawner abundance based solely on expanded observer counts, improving the spawner-recruit analysis, and subsequently calculating the escapement goal range for Unuk River chinook salmon in terms of total large spawners rather than the current survey count range.

Partial counts of large chinook salmon have been conducted on the Unuk River since 1977. Using the expansion factor of 4.99 to estimate the spawning abundance for those years when no mark-recapture estimate is available (1977–1993 and 1995–1996), the estimated abundance of large chinook salmon on the Unuk River has ranged from 2,874 in 1979 to 10,609 in 1986 (Appendix A6). The estimated abundance of 10,541 large chinook salmon in 2001 therefore ranks second in magnitude only to the expanded

Table 5.—Estimated age and sex composition of the escapement of medium (401–659 mm MEF) and large (>659 mm MEF) chinook salmon in the Unuk River in 2001 as determined from spawning grounds samples.

		Brood year and age class				
		1998	1997	1996	1995	1994
		1.1	1.2	1.3	1.4	1.5
Total						
PANEL A: AGE COMPOSITION OF MEDIUM CHINOOK SALMON						
Males	n	8	64	2		74
	%	10.8	86.5	2.7		100.0
	SE of %	3.6	4.0	1.9		
	Escapement	83	665	21		769
	SE of esc.	30	111	15		124
Females	n					
	%					
	SE of %					
	Escapement					
	SE of esc.					
Sexes combined	n	8	64	2		74
	%	10.8	86.5	2.7		100.0
	SE of %	3.6	4.0	1.9		
	Escapement	83	665	21		769
	SE of esc.	30	101	15		124
PANEL B: AGE COMPOSITION OF LARGE CHINOOK SALMON						
Males	n		26	352	86	2
	%		2.6	34.7	8.5	0.2
	SE of %		0.5	1.5	0.9	0.1
	Escapement		270	3,659	894	21
	SE of esc.		60	439	136	15
Females	n		1	312	235	
	%		0.1	30.8	23.2	
	SE of %		0.1	1.4	1.3	
	Escapement		10	3,243	2,443	
	SE of esc.		10	394	307	
Sexes combined	n		27	664	321	2
	%		2.7	65.5	31.7	0.2
	SE of %		0.5	1.5	1.5	0.1
	Escapement		281	6,903	3,337	21
	SE of esc.		62	789	404	15
PANEL C: AGE COMPOSITION OF MEDIUM AND LARGE CHINOOK SALMON						
Males	n	8	90	354	86	2
	%	0.7	8.3	32.5	7.9	0.2
	SE of %	0.3	1.2	1.5	0.8	0.1
	Escapement	83	935	3,680	894	21
	SE of esc.	30	127	439	136	15
Females	n		1	312	235	
	%		0.1	28.7	21.6	
	SE of %		0.1	1.4	1.3	
	Escapement		10	3,243	2,443	
	SE of esc.		10	394	307	
Sexes combined	n	8	91	666	321	2
	%	0.7	8.4	61.2	29.5	0.2
	SE of %	0.3	1.2	1.6	1.4	0.1
	Escapement	83	946	6,923	3,337	21
	SE of esc.	30	127	789	404	15

Table 6.—Estimated average length (MEF in mm) by age, sex and sampling event of chinook salmon sampled in the Unuk River in 2001.

		Brood year and age class					Total
		1998	1997	1996	1995	1994	
		1.1	1.2	1.3	1.4	1.5	
PANEL A: EVENT 1, LOWER UNUK RIVER SET GILLNET							
Males	n	10	96	296	83	2	487
	Avg. length	402	633	813	901	1,000	785
	SD	23	49	60	64	7	118
	SE	7	5	3	7	5	5
Females	n		6	267	125	1	399
	Avg. length		683	825	897	890	845
	SD		15	44	50		60
	SE		6	3	5		3
Sexes combined	n	10	102	563	208	3	886
	Avg. length	402	636	818	899	963	812
	SD	23	50	53	56	64	101
	SE	7	5	2	4	37	3
PANEL B: EVENT 2, SPAWNING GROUNDS							
Males	n	20	90	353	87	2	552
	Avg. length	395	624	811	901	915	780
	SD	26	53	56	66	113	125
	SE	6	6	3	7	80	5
Females	n		1	312	235		548
	Avg. length		675	826	886		851
	SD			38	44		51
	SE			2	3		2
Sexes combined	n	20	91	665	322	2	1,100
	Avg. length	395	624	818	890	915	815
	SD	26	53	49	51	113	102
	SE	6	6	2	3	80	3

Table 7.—Chinook salmon released and recaptured during Event 1 in the lower Unuk River in 2001 and the elapsed time between release and recapture.

Spaghetti tag no.	Release date and time	Recapture date/time	Sulking period	Day	Hr	Min
3436	6/12/2001 11:43	6/27/2001 10:40	14 days, 22 hours, and 57 minutes	14	22	57
3571	7/1/2001 14:30	7/1/2001 17:35	0 days, 3 hours, and 5 minutes		3	5
3540	6/28/2001 17:35	7/3/2001 16:30	4 days, 22 hours, and 55 minutes	4	22	55
3433	6/12/2001 6:30	7/6/2001 6:50	24 days, 0 hours, and 20 minutes	24	0	20
3598	7/6/2001 15:10	7/6/2001 18:26	0 days, 3 hours, and 16 minutes		3	16
3555	6/29/2001 14:51	7/8/2001 17:45	9 days, 2 hours, and 54 minutes	9	2	54
3582	7/3/2001 13:05	7/9/2001 10:30	5 days, 21 hours, and 25 minutes	5	21	25
3597	7/6/2001 10:00	7/10/2001 15:15	4 days, 5 hours, and 15 minutes	4	5	15
3593	7/5/2001 17:30	7/10/2001 15:37	4 days, 22 hours, and 7 minutes	4	22	7
3490	6/26/2001 13:27	7/11/2001 14:50	15 days, 1 hour, and 23 minutes	15	1	23
3625	7/10/2001 10:06	7/11/2001 17:30	1 day, 7 hours, and 24 minutes	1	7	24
3680	7/12/2001 12:00	7/12/2001 13:00	0 days, 1 hour, and 0 minutes		1	0
3699	7/13/2001 10:12	7/13/2001 10:58	0 days, 0 hours, and 46 minutes			46
3637	7/10/2001 16:45	7/13/2001 15:00	2 days, 22 hours, and 15 minutes	2	22	15
3691	7/12/2001 17:45	7/13/2001 16:37	0 days, 22 hours, and 52 minutes		22	52
3710	7/13/2001 17:05	7/13/2001 17:40	0 days, 0 hours, and 35 minutes			35
3506	6/26/2001 17:30	7/14/2001 9:00	17 days, 15 hours, and 30 minutes	17	15	30
3651	7/11/2001 10:30	7/14/2001 11:45	3 days, 1 hour, and 15 minutes	3	1	15
3560	6/29/2001 18:30	7/14/2001 17:00	14 days, 22 hours, and 30 minutes	14	22	30
3504	6/26/2001 16:31	7/14/2001 18:20	18 days, 1 hour, and 49 minutes	18	1	49
3737	7/14/2001 15:00	7/15/2001 9:25	0 days, 18 hours, and 25 minutes		18	25
3766	7/15/2001 9:10	7/15/2001 12:53	0 days, 3 hours, and 43 minutes		3	43
3795	7/15/2001 16:30	7/15/2001 17:10	0 days, 0 hours, and 40 minutes			40
3750	7/14/2001 17:45	7/16/2001 9:15	1 day, 15 hours, and 30 minutes	1	15	30
3700	7/13/2001 12:55	7/16/2001 14:05	3 days, 1 hour, and 10 minutes	3	1	10
3660	7/11/2001 14:10	7/17/2001 7:33	5 days, 17 hours, and 23 minutes	5	17	23
3577	7/12/2001 15:00	7/17/2001 8:13	4 days, 17 hours, and 13 minutes	4	17	13
3767	7/15/2001 9:15	7/17/2001 10:20	2 days, 1 hour, and 5 minutes	2	1	5
3868	7/17/2001 9:15	7/17/2001 10:45	0 days, 1 hour, and 30 minutes		1	30
3840	7/16/2001 14:22	7/17/2001 14:00	0 days, 23 hours, and 38 minutes		23	38
3867	7/17/2001 9:00	7/17/2001 17:15	0 days, 8 hours, and 15 minutes		8	15
3906	7/17/2001 17:50	7/17/2001 18:21	0 days, 0 hours, and 31 minutes			31
3928	7/18/2001 7:05	7/18/2001 14:46	0 days, 7 hours, and 41 minutes		7	41
3950	7/18/2001 13:38	7/18/2001 16:35	0 days, 2 hours, and 57 minutes		2	57
905	7/19/2001 6:00	7/19/2001 17:55	0 days, 11 hours, and 55 minutes		11	55
981	7/24/2001 11:11	7/25/2001 14:29	1 day, 3 hours, and 18 minutes	1	3	18
3986	7/18/2001 17:45	7/25/2001 15:29	6 days, 21 hours, and 44 minutes	6	21	44
1075	7/27/2001 8:20	7/27/2001 11:30	0 days, 3 hours, and 10 minutes		3	10
981	7/25/2001 15:29	7/27/2001 12:50	1 day, 22 hours, and 21 minutes	1	22	21
1097	7/27/2001 13:22	7/28/2001 12:51	0 days, 23 hours, and 29 minutes		23	29
1065	7/26/2001 19:30	7/28/2001 13:30	1 day, 18 hours, and 0 minutes	1	18	0
1060	7/26/2001 18:42	7/28/2001 14:00	1 day, 19 hours, and 18 minutes	1	19	18
1094	7/27/2001 12:50	7/28/2001 14:00	1 day, 1 hour, and 10 minutes	1	1	10
971	7/19/2001 18:25	7/28/2001 17:20	8 days, 22 hours, and 55 minutes	8	22	55
1142	7/29/2001 5:25	7/29/2001 8:45	0 days, 3 hours, and 20 minutes		3	20
1158	7/30/2001 6:05	7/30/2001 12:14	0 days, 6 hours, and 9 minutes		6	9
1107	7/27/2001 16:00	7/30/2001 15:49	2 days, 23 hours, and 49 minutes	2	23	49
1157	7/29/2001 11:05	7/30/2001 16:11	1 day, 5 hours, and 6 minutes	1	5	6
1069	7/27/2001 7:20	7/31/2001 11:20	4 days, 4 hours, and 0 minutes	4	4	0
1245	8/10/2001 10:08	8/24/2001 16:04	14 days, 5 hours, and 56 minutes	14	5	56

Average = 4 days, 5 hours, 36 minutes; maximum = 24 days, 0 hours, 20 minutes; minimum = 0 days, 0 hours, 31 minutes.

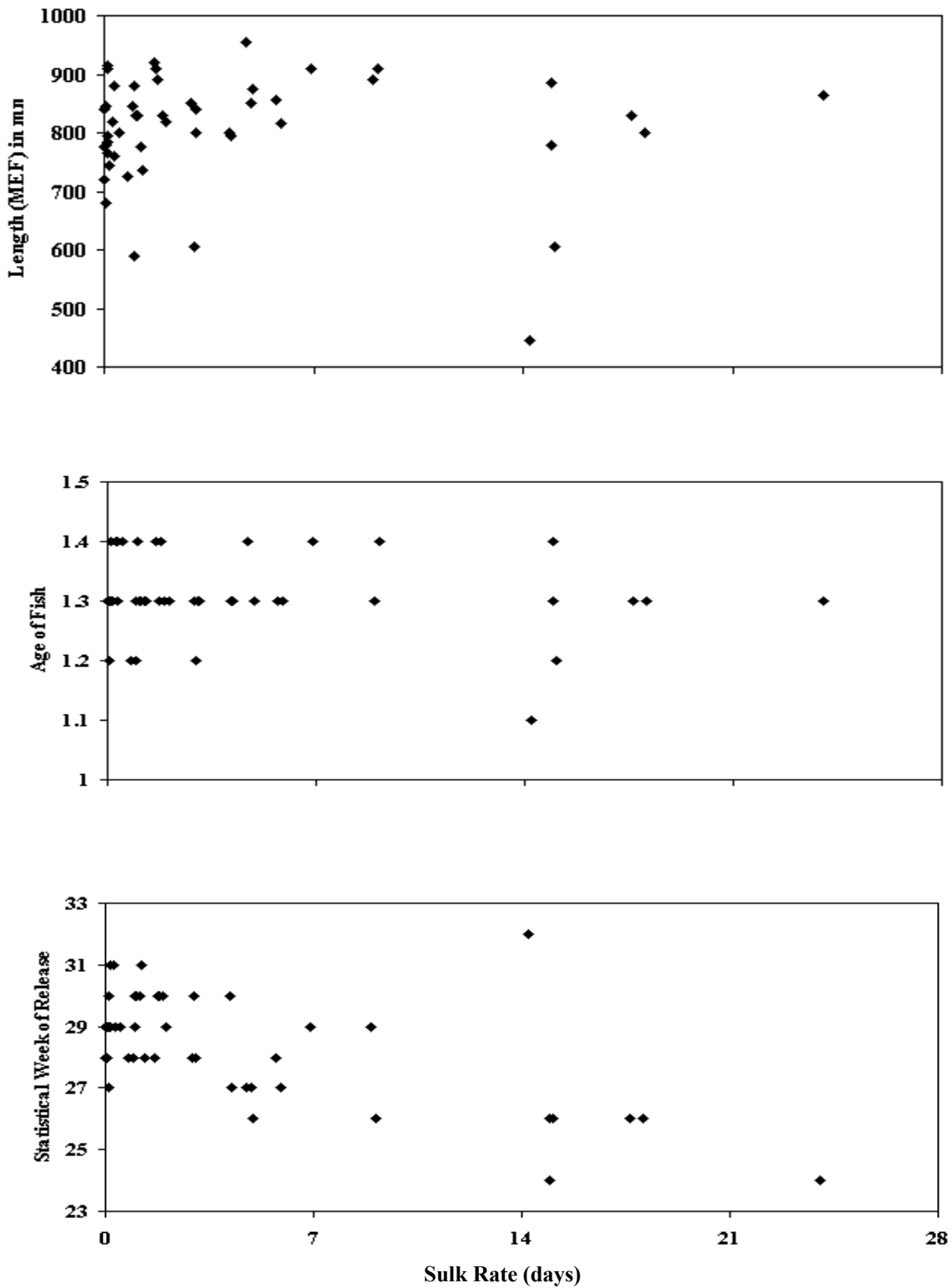


Figure 9.—The elapsed time between release and recapture of chinook salmon caught multiple times in the lower Unuk River set gillnets in 2001 by date of release, fish length, and age of fish.

survey count of 1986 during the past 25 years. As noted, exceptional returns from the 1995 (age-1.4) and 1996 (age-1.3) brood years were primarily responsible for the high escapement in 2001. Preliminary analysis of the 1992–1998 brood years indicates that the estimated abundance of fall fingerlings has averaged 531,468 fish (Appendix A8), with an average overwinter survival rate of 63% (Appendix A7), and an estimated average annual emigration of 333,119 spring smolt. In comparison, estimates for the 1995 brood year indicate fairly average populations of both fingerlings and smolt (545,526 and 321,961 respectively) with a slightly below average overwinter survival of 59%. The 1996 brood year, in contrast, had the highest estimated populations of both fingerlings and smolt (768,427 and 478,914 respectively) and a near average overwinter survival rate of 62%.

CONCLUSIONS AND RECOMMENDATIONS

Because this project will be repeated in 2002, we recommend some strategies for continued success. As in previous years, effort should concentrate on maximizing the numbers of fish tagged during Event 1 and those sampled for tags in Event 2. SN1 should continue to be used as the tagging site since it has produced more than adequate results in prior years. Knowledge of run timing gathered in prior years should be used as an indicator of peak spawning abundance and optimum sampling periods. We recommend that survey counts continue in a similar manner as those made in the past and that observers attempt to maintain consistency in counting efficiency from year to year. Further, we recommend that more effort be applied to the foot surveys to increase the probability of surveying during the period of peak abundance. Finally, the age, sex, and length composition estimates from previous years of study have been relatively unbiased, which can be primarily attributed to the use of diverse capture gear during spawning grounds sampling. We recommend continuing this practice in future years.

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APPENDIX A

Appendix A1.—Numbers of Unuk River chinook salmon fall fry and spring smolt captured and tagged with coded-wire tags, 1992 brood year to present.

Brood year	Year tagged	Fall/spring	Tag code	Dates tagged	Number tagged	Valid tagged
1992	1993	Fall	04-38-03	10/13–10/22/93	10,316	10,263
1992	1993	Fall	04-38-04	10/25/1993	441	433
1992	1993	Fall	04-38-05	10/16–10/21/93	3,202	3,093
1992	1994	Spring	04-42-06	5/05–5/23/94	2,653	2,642
1992 Brood year total					16,612	16,431
1993	1994	Fall	04-33-49	10/07–10/24/94	1,706	1,700
1993	1994	Fall	04-33-50	10/07–10/22/94	11,152	11,139
1993	1994	Fall	04-35-57	10/22–11/01/94	7,688	7,687
1993	1995	Spring	04-42-13	4/10–5/05/95	3,228	3,227
1993 Brood year total					23,774	23,753
1994	1995	Fall	04-35-56	10/07–10/10/95	11,540	11,476
1994	1995	Fall	04-35-58	10/11–10/16/95	11,654	11,645
1994	1995	Fall	04-35-59	10/17–10/24/95	10,825	10,825
1994	1995	Fall	04-42-31	10/25–10/26/95	6,324	6,260
1994	1996	Spring	04-42-07	4/13–4/23/96	6,143	6,099
1994	1996	Spring	04-42-08	4/23–4/27/96	1,362	1,357
1994 Brood year total					47,848	47,662
1995	1996	Fall	04-47-12	9/30–9/15/96	24,252	24,224
1995	1996	Fall	04-42-36	10/16–10/19/96	11,202	11,200
1995	1996	Fall	04-42-18	10/20–10/21/96	3,755	3,753
1995	1997	Spring	04-38-29	3/31–4/18/97	12,521	12,517
1995 Brood year total					51,730	51,694
1996	1997	Fall	04-47-13	10/04–10/11/97	24,309	24,176
1996	1997	Fall	04-47-14	10/06–10/11/97	22,996	22,583
1996	1997	Fall	04-47-15	10/11–10/20/97	15,401	15,146
1996	1998	Spring	04-46-46	3/29–4/05/98	11,193	11,134
1996	1998	Spring	04-43-39	4/08–4/13/98	5,991	5,987
1996 Brood year total					79,890	79,026
1997	1998	Fall	04-01-39	10/04–10/13/98	22,389	22,366
1997	1998	Fall	04-01-40	10/13–10/23/98	11,664	11,522
1997	1999	Spring	04-01-44	4/08–5/01/99	7,954	7,948
1997 Brood year total					42,007	41,836
1998	1999	Fall	04-01-42	10/04–10/17/99	16,677	16,661
1998	2000	Spring	04-02-56	4/01–4/27/00	11,127	11,124
1998	2000	Spring	04-02-57	4/29–5/4/00	2,209	2,209
1998 Brood year total					30,013	29,994
1999	2000	Fall	04-03-74	10/06–10/20/00	21,918	21,853
1999	2000	Fall	04-02-88	10/20–10/29/00	10,082	10,072
1999	2001	Spring	04-01-45	4/2–4/23/01	16,565	16,561
1999 Brood year total					48,565	48,486
2000	2001	Fall	04-02-92	9/29–10/05/01	10,967	10,950
2000	2001	Fall	04-04-57	10/05–10/09/01	11,252	11,231
2000	2001	Fall	04-04-58	10/09–10/14/01	11,259	11,201
2000	2001	Fall	04-04-60	10/14–10/23/01	11,007	10,990
2000	2002	Spring	04-05-38	4/4–4/24/02	10,908	10,904
2000	2002	Spring	04-05-39	4/25–4/26/02	1,093	1,067
2000 Brood year total					56,486	56,343

Appendix A2.—Detection of size-selectivity in sampling and its effects on estimation of size composition.

Results of hypothesis tests (K-S and χ^2) on lengths of fish MARKED during the first event and RECAPTURED during the second event	Results of hypothesis tests (K-S) on lengths of fish CAPTURED during the first event and CAPTURED during the second event
<i>Case I:</i> "Accept" H_0 There is no size-selectivity during either sampling event.	"Accept" H_0
<i>Case II:</i> "Accept" H_0 There is no size-selectivity during the second sampling event but there is during the first.	Reject H_0
<i>Case III:</i> Reject H_0 There is size-selectivity during both sampling events.	"Accept" H_0
<i>Case IV:</i> Reject H_0 There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown.	Reject H_0

Case I: Calculate one unstratified abundance estimate, and pool lengths, sexes, and ages from both sampling events to improve precision of proportions in estimates of composition.

Case II: Calculate one unstratified abundance estimate, and only use lengths, sexes, and ages from the second sampling event to estimate proportions in compositions.

Case III: Completely stratify both sampling events, and estimate abundance for each stratum. Add abundance estimates across strata to get a single estimate for the population. Pool lengths, ages, and sexes from both sampling events to improve precision of proportions in estimates of composition, and apply formulae to correct for size bias to the pooled data (p. 17).

Case IV: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata to get a single estimate for the population. Use lengths, ages, and sexes from only the second sampling event to estimate proportions in compositions, and apply formulae to correct for size bias to the data from the second event.

Whenever the results of the hypothesis tests indicate that there has been size-selective sampling (Case III or IV), there is still a chance that the bias in estimates of abundance from this phenomenon is negligible. Produce a second estimate of abundance by not stratifying the data as recommended above. If the two estimates (stratified and unbiased vs. biased and unstratified) are dissimilar, the bias is meaningful, the stratified estimate should be used, and data on compositions should be analyzed as described above for Cases III or IV. However, if the two estimates of abundance are similar, the bias is negligible in the UNSTRATIFIED estimate, and analysis can proceed as if there were no size-selective sampling during the second event (Cases I or II).

Appendix A3.—Numbers by sex and age for chinook salmon sampled on the Unuk River spawning grounds in 2001 by location (Panel A), gear (Panel B), and size group (Panel C), and in the lower river gillnet samples (Panel D). Results were not stratified by size class; for the age composition of the escapement, see Table 5.

			Brood year and age class					
			1998	1997	1996	1995	1994	
			1.1	1.2	1.3	1.4	1.5	Total
PANEL A: EVENT 2 SAMPLES BY LOCATION								
Boundary Creek	Males	n		6	5			11
		%		20.0	16.7			36.7
	Females	n		1	15	3		19
		%		3.3	50.0	10.0		63.3
	Total	n		7	20	3		30
%			23.3	66.7	10.0		100.0	
Clear Creek	Males	n	1	17	78	28	1	125
		%	0.5	7.7	35.1	12.6	0.5	56.3
	Females	n			48	49		97
		%			21.6	22.1		43.7
	Total	n	1	17	126	77	1	222
%		0.5	7.7	56.8	34.7	0.5	100.0	
Cripple Creek	Males	n	1	36	108	32		177
		%	0.3	9.0	27.0	8.0		44.3
	Females	n			109	114		223
		%			27.3	28.5		55.8
	Total	n	1	36	217	146		400
%		0.3	9.0	54.3	36.5		100.0	
Eulachon	Males	n	1	2	26	10		39
		%	1.1	2.1	27.7	10.6		41.5
	Females	n			32	23		55
		%			34.0	24.5		58.5
	Total	n	1	2	58	33		94
%		1.1	2.1	61.7	35.1		100.0	
Gene's Lake Creek ^a	Males	n	17	25	105	9		156
		%	6.0	8.8	36.9	3.2		54.9
	Females	n			99	29		128
		%			34.9	10.2		45.1
	Total	n	17	25	204	38		284
%		6.0	8.8	71.8	13.4		100.0	
Lake Creek	Males	n		3	19	6	1	29
		%		6.0	38.0	12.0	2.0	58.0
	Females	n			7	14		21
		%			14.0	28.0		42.0
	Total	n		3	26	20	1	50
%		0.0	6.0	52.0	40.0	2.0	100.0	
All other tributaries ^b	Males	n		1	13	1		15
		%		4.8	61.9	4.7		71.4
	Females	n			2	4		6
		%			9.5	19.0		28.6
	Total	n		1	15	5		21
%			4.8	71.4	23.8		100.0	

Appendix A3.-(Page 2 of 3).

		Brood year and age class					Total	
		1998	1997	1996	1995	1994		
		1.1	1.2	1.3	1.4	1.5		
PANEL B: EVENT 2 SAMPLES BY GEAR								
Carcass	Males	n	2	5	31	11	49	
		%	1.5	3.7	22.9	8.2	36.3	
	Females	n			55	31	86	
		%			40.7	23.0	63.7	
	Total	n	2	5	86	42	135	
		%	1.5	3.7	63.7	31.1	100.0	
Dipnet	Males	n	2	1	1		4	
		%	50.0	25.0	25.0		100.0	
	Females	n						
		%						
	Total	n	2	1	1		4	
		%	50.0	25.0	25.0		100.0	
Rod and reel lure	Males	n	1		1		2	
		%	20.0		20.0		40.0	
	Females	n			3		3	
		%			60.0		60.0	
	Total	n	1		4		5	
		%	20.0		80.0		100.0	
Rod and reel snag	Males ^c	n	14	72	288	67	2	443
		%	1.7	8.7	34.8	8.1	0.2	53.5
	Females	n		1	216	168		385
		%		0.1	26.1	20.3		46.5
	Total	n	14	73	504	235	2	828
		%	1.7	8.8	60.9	28.4	0.2	100.0
Spear	Males	n	1	12	33	8		54
		%	0.8	9.3	25.6	6.2		41.8
	Females	n			38	37		75
		%			29.5	28.7		58.1
	Total	n	1	12	71	45		129
		%	0.8	9.3	55.0	34.9		100.0

-continued-

Appendix A3.-(Page 3 of 3).

			Brood year and age class					Total	
			1998	1997	1996	1995	1994		
			1.1	1.2	1.3	1.4	1.5		
PANEL C: EVENT 2—ALL TRIBUTARIES COMBINED									
Spawning grounds	Medium-sized	Males	n	8	64	2		74	
			%	10.8	86.5	2.7		100.0	
		Females	n						
			%						
		Total	n	8	64	2		86	
			%	10.8	86.5	2.7		100.0	
	Large-sized	Males	n		26	352	86	2	466
			%		2.6	34.7	8.5	0.2	46.0
		Females	n		1	312	235		548
			%		0.1	30.8	23.		54.0
		Total	n		27	664	321	2	1,014
			%		2.7	65.5	31.7	0.2	100.0
Medium and large-sized	Males	n	8	90	354	86	2	540	
		%	0.7	8.3	32.5	7.9	0.2	49.6	
	Females	n		1	312	235		548	
		%		0.1	28.7	21.6		50.4	
	Total	n	8	91	666	321	2	1,088	
		%	0.7	8.4	61.2	29.5	0.2	100.0	
PANEL D: EVENT 1—LOWER UNUK RIVER SET GILLNET SAMPLES									
Event 1	Medium-sized	Males ^d	n	10	71	4	1	86	
			%	11.6	82.6	4.6	1.2	100.0	
		Females	n						
			%						
		Total	n	10	71	4	1	86	
			%	11.6	82.6	4.7	1.2	100.0	
	Large-sized	Males ^e	n		25	292	82	2	401
			%		3.1	36.6	10.3	0.3	50.3
		Females	n		6	266	124	1	397
			%		0.8	33.3	15.5	0.1	49.7
		Total	n		31	558	206	3	798
			%		3.9	69.%	25.8	0.4	100.0
Medium and large-sized	Males	n	10	96	296	83	2	487	
		%	1.1	10.9	33.5	9.4	0.2	55.1	
	Females	n		6	266	124	1	397	
		%		0.7	30.1	14.0	0.1	44.9	
	Total	n	10	102	562	207	3	884	
		%	1.1	11.5	63.6	23.4	0.3	100.0	

^a One fish for which neither age nor length was determined is not included.

^b Includes Boulder Creek, Kerr Creek, and Chum Creek.

^c Not included is one fish for which age was not determined.

^d Not included is one fish for which age was not determined.

^e Not included are four fish for which age was not determined.

Appendix A4.—Estimated annual escapement of chinook salmon in the Unuk River by age class and sex, 1997–2001.

		AGE CLASS						Total
Year		1.1	1.2	2.2	1.3	1.4	1.5	
1997 estimated escapement	Male	46	881	5	724	323	14	1,992
	%	1.3	24.0	0.1	19.7	8.8	0.4	54.3
	Female		5		526	1,102	46	1,679
	%		0.1		14.3	30.0	1.3	45.7
	Total	46	885	5	1,250	1,425	60	3,671
	%	1.3	24.1	0.1	34.0	38.8	1.6	100.0
1998 estimated escapement	Male	232	1,299	6	1,392	325	6	3,259
	%	4.4	24.4	0.1	26.1	6.1	0.1	61.2
	Female				1,172	870	29	2,071
	%				22.0	16.3	0.5	38.8
	Total	232	1,299	6	2,564	1,195	35	5,330
	%	4.4	24.4	0.1	48.1	22.4	0.7	100.0
1999 estimated escapement	Male	211	2,189		1,134	492	9	4,036
	%	3.4	35.4		18.3	8.0	0.1	65.3
	Female		26		914	1,196	9	2,145
	%		0.4		14.8	19.3	0.1	34.7
	Total	211	2,216		2,049	1,688	18	6,181
	%	3.4	35.8		33.1	27.3	0.3	100.0
2000 estimated escapement	Male	9	2,444		2,312	517	19	5,302
	%	0.1	30.0		28.4	6.3	0.2	65.1
	Female		47		1,636	1,128	38	2,848
	%		0.6		20.1	13.8	0.5	34.9
	Total	9	2,491		3,948	1,645	56	8,150
	%	0.1	30.6		48.4	20.2	0.7	100.0
2001 estimated escapement	Male	83	935		3,680	894	21	5,613
	%	0.7	8.3		32.5	7.9	0.2	59.6
	Female		10		3,243	2,443		5,697
	%		0.1		28.7	21.6		50.4
	Total	83	946		6,923	3,337	21	11,310
	%	0.7	8.4		61.2	29.4	0.2	100.0
1997–2001 average annual estimated escapement	Male	116	1,550	2	1,849	510	14	4,041
	%	1.7	22.5	0.0	26.7	7.4	0.2	58.3
	Female		18		1,498	1,348	24	2,888
	%		0.3		21.6	19.5	0.4	41.7
	Total	116	1,567	2	3,347	1,858	38	6,928
	%	1.7	22.6	0.0	48.3	26.8	0.5	100.0

Appendix A5.—Numbers of adult Unuk River chinook salmon examined for adipose finclips, sacrificed for CWT sampling purposes, valid CWT tags decoded, percent of the marked fraction carrying germane CWTs, percent adipose clipped, and estimated fraction of the sample carrying valid CWTs, 1992 brood year to present.

Brood year	Age class	Year examined	Number examined	Adipose clips	Number sacrificed	Number of valid tags				Percent adipose	Marked fraction (θ)	
						Fall	Spring	Total	Valid		Valid	Event
1992	1.2	1996	33	0								1+2
1992	1.3	1997	161	7	7	6	1	7	100.0%	4.3%	4.3%	1
1992	1.3	1997	324	7	4	4	0	4	100.0%	2.2%	2.2%	2
1992	2.2	1997	1	0								2
1992	1.4	1998	139	6	4	2	2	4	100.0%	4.3%	4.3%	1
1992	1.4	1998	207	10	4	2	2	4	100.0%	4.8%	4.8%	2
1992	1.5	1999	2	0								2
1992 Brood year total			867	30	19	14	5	19	100.0%	3.5%	3.5%	
1993	1.1	1996	4	1	1	1	0	1	100.0%	25.0%	25.0%	2
1993	1.2	1997	106	9	9	8	1	9	100.0%	8.5%	8.5%	1
1993	1.2	1997	203	31	26	20	2	22	84.6%	15.3%	12.9%	2
1993	1.3	1998	348	31	28	24	4	28	100.0%	8.9%	8.9%	1
1993	1.3	1998	439	31	15	11	4	15	100.0%	7.1%	7.1%	2
1993	2.2	1998	1	0								2
1993	1.4	1999	141	10	1	1	0	1	100.0%	7.1%	7.1%	1
1993	1.4	1999	205	27	16	12	4	16	100.0%	13.2%	13.2%	2
1993	1.5	2000	3	0								1
1993	1.5	2000	6	0								2
1993 Brood year total			1,456	140	96	77	15	92	95.8%	9.6%	9.2%	
1994	1.1	1997	60	4	4	2	2	4	100.0%	6.7%	6.7%	2
1994	1.2	1998	107	10	9	4	5	9	100.0%	9.3%	9.3%	1
1994	1.2	1998	224	20	16	10	6	16	100.0%	8.9%	8.9%	2
1994	2.1	1998	1	0								2
1994	1.3	1999	179	18	1	1	0	1	100.0%	10.1%	10.1%	1
1994	1.3	1999	254	27	11	6	5	11	100.0%	10.6%	10.6%	2
1994	1.4	2000	89	2	0					2.2%		1
1994	1.4	2000	175	11	7	3	3	6	85.7%	6.3%	5.4%	2
1994	1.5	2001	3	0								1
1994	1.5	2001	2	0								2
1994 Brood year total			1,094	92	48	26	21	47	97.9%	8.4%	8.2%	
1995	1.1	1998	8	1	1	1	0	1	100.0%	12.5%	12.5%	1
1995	1.1	1998	69	14	12	12	0	12	100.0%	20.3%	20.3%	2
1995	1.2	1999	203	22	20	15	5	20	100.0%	10.8%	10.8%	1
1995	1.2	1999	280	41	26	15	11	26	100.0%	14.6%	14.6%	2
1995	1.3	2000	353	27	1	0	1	1	100.0%	7.6%	7.6%	1
1995	1.3	2000	419	47	18	10	6	16	88.9%	11.2%	10.0%	2
1995	1.4	2001	207	22	2	1	1	2	100.0%	10.6%	10.6%	1
1995	1.4	2001	322	31	17	11	6	17	100.0%	9.6%	9.6%	2
1995 Brood year total			1,861	205	97	65	30	95	97.9%	11.0%	10.8%	

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Appendix A5.–Page 2 of 2.

Brood year	Age class	Year examined	Number examined	Adipose clips	Number sacrificed	Number of valid tags				Percent adipose	Marked fraction (θ)	
						Fall	Spring	Total	Valid		Valid	Event
1996	0.1	1998	1	0								2
1996	1.1	1999	4	0								1
1996	1.1	1999	55	7	5	4	1	5	100.0%	12.7%	12.7%	2
1996	1.2	2000	287	36	24	16	8	24	100.0%	12.5%	12.5%	1
1996	1.2	2000	266	36	25	17	6	23	92.0%	13.5%	12.5%	2
1996	1.3	2001	563	59	4	3	1	4	100.0%	10.5%	10.5%	1
996	1.3	2001	666	84	39	24	10	34	87.2%	12.6%	11.0%	2
1996 Brood year total			1,842	222	97	64	26	90	92.8%	12.1%	11.2%	
1997	1.1	2000	1	0								1
1997	1.1	2000	10	1	1	0	1	1	100.0%	10.0%	10.0%	2
1997	1.2	2001	102	17	14	8	3	11	78.6%	16.7%	13.1%	1
1997	1.2	2001	91	10	9	4	2	6	66.7%	11.0%	7.3%	2
1997 Brood year total			204	28	24	12	6	18	75.0%	13.7%	10.3%	
1998	1.1	2001	10	1	1	0	1	1	100.0%	10.0%	10.0%	1
1998	1.1	2001	20	2	2	0	2	2	100.0%	10.0%	10.0%	2
1998 Brood year total			30	3	3	0	3	3	100.0%	10.0%	10.0%	

Appendix A6.—Estimated abundance of the spawning population of large (>659 mm MEF) chinook salmon in the Unuk River, 1977–2001. Mean expansion factor is 4.99 (SD = 0.53).

Year	Peak count from surveys	Abundance estimated from expanded count		Abundance estimated from m-r experiment		Preferred abundance estimate	
		\hat{N}	SE (\hat{N})	\hat{N}	SE (\hat{N})	\hat{N}	SE (\hat{N})
1977	974	4,860	516			4,860	516
1978	1,106	5,519	586			5,519	586
1979	576	2,874	305			2,874	305
1980	1,016	5,070	538			5,070	538
1981	731	3,648	387			3,648	387
1982	1,351	6,741	716			6,741	716
1983	1,125	5,614	596			5,614	596
1984	1,837	9,167	974			9,167	974
1985	1,184	5,908	628			5,908	628
1986	2,126	10,609	1,127			10,609	1,127
1987	1,973	9,845	1,046			9,845	1,046
1988	1,746	8,713	925			8,713	925
1989	1,149	5,734	609			5,734	609
1990	591	2,949	313			2,949	313
1991	655	3,268	347			3,268	347
1992	874	4,361	463			4,361	463
1993	1,068	5,329	566			5,329	566
1994	711	3,548	377			4,623	377
1995	772	3,852	409			3,852	409
1996	1,167	5,823	619			5,823	619
1997	636	3,174		2,970	271	2,970	271
1998	840	4,192		4,132	394	4,132	394
1999	680	3,393		3,914	480	3,914	480
2000	1,341	6,692		5,872	620	5,872	620
2001	2,019	10,075		10,541	1,181	10,541	1,181

Appendix A7.—Estimation of the overwinter survival of Unuk River chinook salmon fingerlings, 1992–1998 brood years.

The overwinter survival of chinook salmon fingerlings marked in the fall can be estimated as the relative odds of survival against smolts marked the following spring. If M_f is the number of fingerlings marked in the fall, the expected number of coded-wire tags (CWTs) recovered from adults would be:

$$E(m_f) = M_f S_w S_o \Phi \quad (1)$$

where S_w is the probability of a fingerling surviving the winter, S_o the probability of a smolt surviving to return as an adult, and Φ is the probability that an adult is caught and its CWT recovered. Note that recoveries occur over five ocean ages (age-.1 to -.5) for a particular brood. In this instance recovery is by any means: random and select, inriver escapement and marine fisheries. A similar expression can be written for the expected number of tags recovered from adults that were coded-wire tagged as smolt:

$$E(m_s) = M_s S_o \Phi \quad (2)$$

These expressions can be rearranged to express the overwinter probability of survival as a function of expected recoveries and numbers tagged:

$$S_w = \frac{M_s m_f}{m_s M_f} = \frac{\hat{p}_f}{\hat{p}_s} \quad (3)$$

where m_f is the number of fall CWTs recovered, m_s is the number of spring CWTs recovered, \hat{p}_f and \hat{p}_s are estimated recovery rates, and \hat{p}_f / \hat{p}_s is the odds ratio. Because recoveries were considered to follow binomial distributions, estimated variance rates were calculated as follows:

$$\text{var}(\hat{p}_f) = \frac{\hat{p}_f(1 - \hat{p}_f)}{M_f - 1} \quad (4)$$

$$\text{var}(\hat{p}_s) = \frac{\hat{p}_s(1 - \hat{p}_s)}{M_s - 1} \quad (5)$$

$$\text{var}(\hat{S}_w) \cong \hat{S}_w^2 [\text{cv}^2(\hat{p}_f) + \text{cv}^2(\hat{p}_s)] \quad (6)$$

where eq. 6 was derived using the delta method as described in Seber (1982), p. 8. The estimated number of smolt that had been tagged as fingerlings $\hat{M}_{f \rightarrow s}$ was calculated as:

$$\hat{M}_{f \rightarrow s} = \hat{S}_w M_f \quad (7)$$

$$\text{var}(\hat{M}_{f \rightarrow s}) = \text{var}(\hat{S}_w) M_f^2 \quad (8)$$

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Appendix A7.–Page 2 of 2.

The resulting estimates are:

Brood year	Year tagged	Season	Number tagged	Tags recovered	Recovery years	\hat{S}_f	SE (\hat{S}_f)	$\hat{M}_{f \rightarrow s}$	SE ($\hat{M}_{f \rightarrow s}$)	Estimated number of emigrants tagged
1992	1993	Fall	13,789	21	1995–1999	0.805	0.400	11,096	5,519	
1992	1994	Spring	2,642	5	1995–1999					13,738
1993	1994	Fall	20,524	108	1996–2000	0.772	0.180	15,842	3,695	
1993	1995	Spring	3,227	22	1996–2000					19,069
1994	1995	Fall	40,208	50	1997–2001	0.343	0.082	13,807	3,289	
1994	1996	Spring	7,456	27	1997–2001					21,263
1995	1996	Fall	39,177	133	1998–2001	0.590	0.086	23,122	3,374	
1995	1997	Spring	12,517	72	1998–2001					35,639
1996	1997	Fall	61,905	151	1999–2001	0.623	0.091	38,582	5,652	
1996	1998	Spring	17,119	67	1999–2001					55,701
1997	1998	Fall	33,898	37	2000–2001	0.667	0.215	22,621	7,285	
1997	1999	Spring	7,948	13	2000–2001					30,569
1998	1999	Fall	16,661	18	2001	0.800	0.267	13,333	4,440	
1998	2000	Spring	13,333	18	2001					26,666

Statistics for brood years 1996 and younger should be considered preliminary since more CWTs will be recovered from these brood years in the future.

Appendix A8.—Estimation of Unuk River chinook salmon smolt (N_s) and fingerling (N_f) abundance, 1992–1998 brood years.

Abundance of smolt emigrating from the Unuk River was estimated with a two-event mark-recapture study using Chapman’s modification of the Peterson estimate (Chapman 1951):

$$\hat{N}_s = \frac{(M_s + 1)(n_e + 1)}{(m_a + 1)} - 1 \quad (1)$$

$$\text{var}(\hat{N}_s) = \frac{(M_s + 1)(n_e + 1)(M_s - m_a)(n_e - m_a)}{(m_a + 1)^2(m_a + 2)} \quad (2)$$

where \hat{N}_s was the number of smolt emigrating, M_s was the number of smolt tagged, n_e was the total number of adults sampled from a particular brood year, and m_a was the number of adults in that sample with missing adipose fins. Fingerling abundance, \hat{N}_f , was estimated as:

$$\hat{N}_f = \hat{N}_s \frac{1}{\hat{S}_w} \quad (3)$$

$$\text{var}(\hat{N}_f) \cong \hat{N}_f^2 [\text{cv}^2(\hat{N}_s) + \text{cv}^2(\hat{S}_w)] \quad (4)$$

where \hat{S}_w here is the overwinter survival rate of fingerlings (Appendix A7). Eq. 4 was derived using the delta method as described in Seber (1982), p. 8.

The resulting estimates are:

Brood year	M_s	Recovery years	n_e	m_a	\hat{N}_s	$\text{se}(\hat{N}_s)$	\hat{N}_f	$\text{se}(\hat{N}_f)$
1992	13,738	1996–1999	867	30	384,702	66,706	477,052	251,660
1993	19,069	1996–2000	1,456	140	197,052	15,658	255,295	62,878
1994	21,263	1997–2001	1,094	92	250,370	24,649	729,093	188,342
1995	35,639	1998–2001	1,869	206	321,961	20,991	545,526	87,233
1996	55,701	1999–2001	2,415	280	478,914	26,742	768,427	120,550
1997	30,569	2000–2001	825	88	283,718	28,208	425,153	143,424
1998	26,666	2001	466	29	415,115	72,082	518,731	194,938
Mean	28,949		1,285	124	333,119	15,940	531,468	61,190

Statistics for brood years 1996 and younger should be considered preliminary since more CWTs will be recovered from these brood years in the future.

Appendix A9.—Computer files used to estimate the spawning abundance of chinook salmon in the Unuk River in 2001.

File name	Description
01unk41a.xls	Spreadsheet containing all the mark-recapture data with various pivot table results, Tables 1 and 3– 7, Figures 5–8, Appendices A1, A3, A4, and A6, abundance estimates, and chi-squared analyses.
01unuk41b.xls	Spreadsheet containing Appendix A5.
01unuk41c.xls	Spreadsheet containing Tables 2 and Figure 9.
01unuksmoltap.xls	Spreadsheet containing smolt overwinter survival and abundance tables for Appendices A7 and A8.
Unuk01bootstrap.xls	File containing bootstrap results.